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Reuse and Renovation of Sewage Stabilization Pond Effluent Through Irrigation

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REUSE AND RENOVATION OF SEWAGE STABILIZATION POND EFFLUENT THROUGH IRRIGATION

by

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16. ABSTRACT

The main objective of this project was to explore the recycling of stabilized pond effluent to grow crops for municipal beautification. The research encompassed pond effluent quality, irrigation site parameters, crop responses, renovation qualities of site and crops, insects and winter irrigation. Levels of wastewater application were 51, 76, and 102 mm per week. The solid-set, buried, automatic lateral-change irrigation system functioned well. The glacial till soils, however, varied to such an extent that greater drainage problems occurred in the 51 mm application area than in the 102 mm application area. Ground water samples indicated that the soil and crops essentially removed all irrigated phosphorus. Nearly all crops indicated nutrient deficiencies, especially nitrogen. Mosquito species and numbers increased but did not stabilize in poorly-drained areas during two years of insect observations. Wastewater was applied successfully under severe winter conditions. Irrigated sod crops showed little or no stress from the four years of winter application. Observed runoff seemed to be due more to compacted soils than to "frozen" soils.

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C Galegar

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Director
Robert S. Kerr Environmental Research Laboratory

ABSTRACT

The main objective of this project was to explore the recycling of stabilized pond effluent to grow crops for municipal beautification. The research encompassed pond effluent quality, irrigation site parameters, crop responses, renovation qualities of site and crops, insects and winter irrigation.

The Belding (5,000 population) sewage treatment system of five stabilization ponds (21 ha) ordinarily operates on a twice-a-year fill and draw basis. Ammonia nitrogen and total phosphorus levels of the pond effluent during the irrigation season average about 1.3 and 2.0 mg/l, respectively.

Levels of wastewater application were 51, 76 and 102 mm per week. The solid-set, buried, automatic lateral-change irrigation system functioned well. The glacial till soils, however, varied to such an extent that greater drainage problems occurred in the 51 mm application area than in the 102 mm application area.

Beneficial responses were obtained on well-managed and well-drained areas of ornamental trees and sod crops with up to 102 mm per week of effluent application. Nursery type management of the trees is required if high quality trees are desired.

Ground water samples indicated that the soil and crops essentially removed all irrigated phosphorus. Nearly all crops indicated nutrient deficiencies, especially nitrogen.

Mosquito species and numbers increased but did not stabilize in poorly-drained areas during two years of insect observations.

Wastewater was applied successfully under severe winter conditions. Irrigated sod crops showed little or no stress from the four years of winter application. Observed runoff seemed to be due more to compacted soils than to "frozen" soils.

This report was submitted in fulfillment of Grant No. S803807 (formerly 16080 FOC) by the City of Belding, Michigan, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period April 1, 1970, to June 30, 1978, and work was completed as of June 1, 1979.

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ENGLISH - METRIC CONVERSION FACTORS

To convert from	To	Multiply by
inch	meter (m)	0.0254
feet	meter (m)	0.3048
acre	meter^2 (m^2)	4047.
acre	hectare (ha)	0.4047
gallon	meter^3 (m^3)	0.003785
gallon	liter (l)	3.785
gallon/minute	liter/second (l/s)	0.06309
pound/inch^2	pascal (Pa)	6895.
pound/acre	kilogram/hectare (kg/ha)	1.121
pound	kilogram (kg)	0.4536
°F-32	°C	0.5556

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A Federal Water Pollution Control Administration grant was received for the inception of the project in April, 1970, and subsequent grants from the Federal Water Quality Administration and Environmental Protection Agency continued to support the project through March, 1977. Assistance of the original Project Officer, Ralph Christensen; the present Project Officer, James Phillips; and EPA's Technical Support Officer, Richard Thomas is particularly acknowledged.

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SECTION 1

INTRODUCTION

The 1968 Lake Michigan Enforcement Conference of the Federal Water Pollution Control Administration (FWPCA), forerunner of the U.S. Environmental Protection Agency (USEPA), ruled that all municipal and industrial wastewaters were to be given the equivalent of secondary treatment and 80 percent phosphorus removal by the end of 1972. This ruling gave added impetus to the existing concern for alleviating degradation of streams and lakes. Dilution of wastewater in natural stream courses was no longer a satisfactory method of handling liquid wastes because it too frequently caused excessive growth of aquatic weeds which detracts from the aesthetic and recreational values of the water resource.

Phosphorus removal from effluent of sewage oxidation pond treatment systems poses an extensive problem in the North Central Region since there are many pond systems already existing and many more being constructed. No practical method presently exists for removing adequate amounts of phosphorus from algae laden pond discharge.

The City of Belding, instead of trying to meet merely the minimum requirements of phosphorus removal by 1972, chose to take a much broader approach. The officials reasoned that, as time goes by, phosphorus removal alone will not be sufficient; therefore, they elected to remove not only phosphorus but also additional nutrients by irrigating crops with their oxidation pond effluent. Also in addition to agricultural crops, they wished to grow vegetative materials for the beautification of the city.

In December, 1969, the City requested aid from the Federal Water Pollution Control Administration in the form of a research, development and demonstration grant for implementing this environment enhancing venture. In April, 1970, the project was officially started. The overall purpose of the project was to develop guidelines for possible full-scale use of this concept for North Central cities facing a similar problem. The present publication is a summary report of the activities during the seven-year period of this endeavor. A listing of the original project objectives follows:

a. Demonstrate feasibility of spray irrigation of chlorinated sewage oxidation pond effluent.

b. Develop design parameters for full-scale operation at Belding as well as other similar installations in northern climates where soil is generally glacial drift.

c. Demonstrate use of water and nutrients for crops having direct municipal use; i.e., sod farm and tree nursery.

d. Demonstrate value of balanced cropping in removal of nutrients from treated wastewater prior to recharge into ground water reservoir.

e. Determine species of insects indigenous to the treatment site and develop methods of control of flying insects.

SECTION 2

CONCLUSIONS

1. Effluent produced by a five-cell sewage oxidation pond system is satisfactory after chlorination for land application and it is possible to apply this effluent through spray irrigation systems during summer and winter seasons under North Central United States climate conditions.

2. Stabilization ponds operated on a fill and draw basis have much higher levels of phosphorus and ammonia nitrogen in the discharge cell during early spring and late fall (when they frequently are discharged into streams) than in summer (when they are irrigated).

3. Increases in ground water elevation due to wastewater irrigation of naturally poorly-drained glacial drift soils cause hydrological problems, crop damage, and mosquito habitats.

4. Natural drainage of glacial drift soils varies to such a degree that greater drainage problems can occur from a 51 millimeters (mm) weekly application level than from a 102 mm application level.

5. Management in the control of weeds and wetness of sites sprayed with sewage oxidation pond effluent is critical for survival of crops grown for municipal use even under a 51 mm per week application level.

6. Addition of irrigated effluent, up to 102 mm per week, has a beneficial effect on well-maintained and well-drained areas of shade trees, sod and forage crops.

7. Many types of ornamental trees for municipal beautification can be grown from seedlings to the transplanting stage under wastewater irrigation in three to four years. Under proper management, these trees will equal or excel in growth and quality trees grown under normal nursery management.

8. Turf for municipal beautification grows well under wastewater irrigation; however, the level of management and the type of rock-free soil required could make it a non cost-effective method.

9. Municipal crops in conjunction with the soil on which they are grown remove essentially all the phosphorus from 51, 76 and 102 mm weekly applications of sewage oxidation pond effluent.

10. Nitrogen levels of the ground water beneath the irrigation sites were very low; however, the nitrogen level in pond effluent used for irrigation was even lower. Most crops irrigated showed a nitrogen deficiency.

11. Operation of spray irrigation systems in close proximity to sewage oxidation ponds has produced new aquatic ecological niches that became occupied by mosquito species that either formerly were not present in the area or were present in such small numbers as to have been of no practical significance.

12. Wastewater was successfully distributed on the land under severe winter conditions and the various sod crops irrigated have shown no stress from the four years of winter application.

SECTION 3

RECOMMENDATIONS

Since it has been established that crop damage is occurring due to high ground water levels under the summer irrigation site, irrigation application rates and/or surface and subsurface drainage facilities should be modified to demonstrate operational techniques available to manage wastewater irrigation systems.

Wastewater irrigation with higher levels of phosphorus and nitrogen, as from cell 2, should be evaluated in order to recycle more of the effluent nutrients as well as supply crop needs.

Monitoring of the water quality in all five cells should be repeated for a two-year period to determine if the system is losing its ability to reduce phosphorus levels from influent to effluent.

Detailed monitoring of the quantity and quality of runoff from the winter irrigation site under modified application rates and soil conditions is needed to evaluate the potential of winter spray irrigation under North Central United States climatic conditions.

Entomological studies should be continued at the Belding spray irrigation site to determine whether or not the observed changes in the diversity and populations of mosquitoes will stabilize.

SECTION 4

SEWAGE OXIDATION POND SYSTEM

Descriptive aspects of the five-cell oxidation pond system and chemical aspects of the wastewater, as it enters and flows from cell 1 through cell 5, are included in this section.

DESCRIPTIVE ASPECTS

The City of Belding is located in Ionia County in the west central part of Michigan (Figure 1). The oxidation pond system and irrigation research sites are situated southeast of the City on approximately 40 hectares (ha) bounded on the west by the Chesapeake and Ohio Railroad and on the remaining periphery by the Flat River.

The wastewater which enters the pond system is a composite of sewage from the City of Belding and of a significant portion of the City's stormwater from storms with less than 10-year frequency of occurrence. Removal of water from the ponds is by irrigation of the research sites and by drawing the cells down to a minimum level with direct discharge into the Flat River two or three times a year.

Arrangement of the five-cell oxidation pond treatment facility is shown in Figure 1 and the size of each cell is indicated in Table 1. The total pond water surface area as noted in Table 1 is approximately 21 ha.

TABLE 1. SURFACE AREA AND CAPACITY OF BELDING'S FIVE-CELL SEWAGE TREATMENT FACILITY

Cell (No.)	Cell Area (ha)	Cell Capacity (ha-m)	Cell Capacity (m^3)
1	0.4	1.06	10,598
2	8.2	15.3	153,291
3	6.1	11.3	112,793
4	3.0	5.5	55,261
5	3.0	5.5	55,261
Total	20.7	38.7	387,204

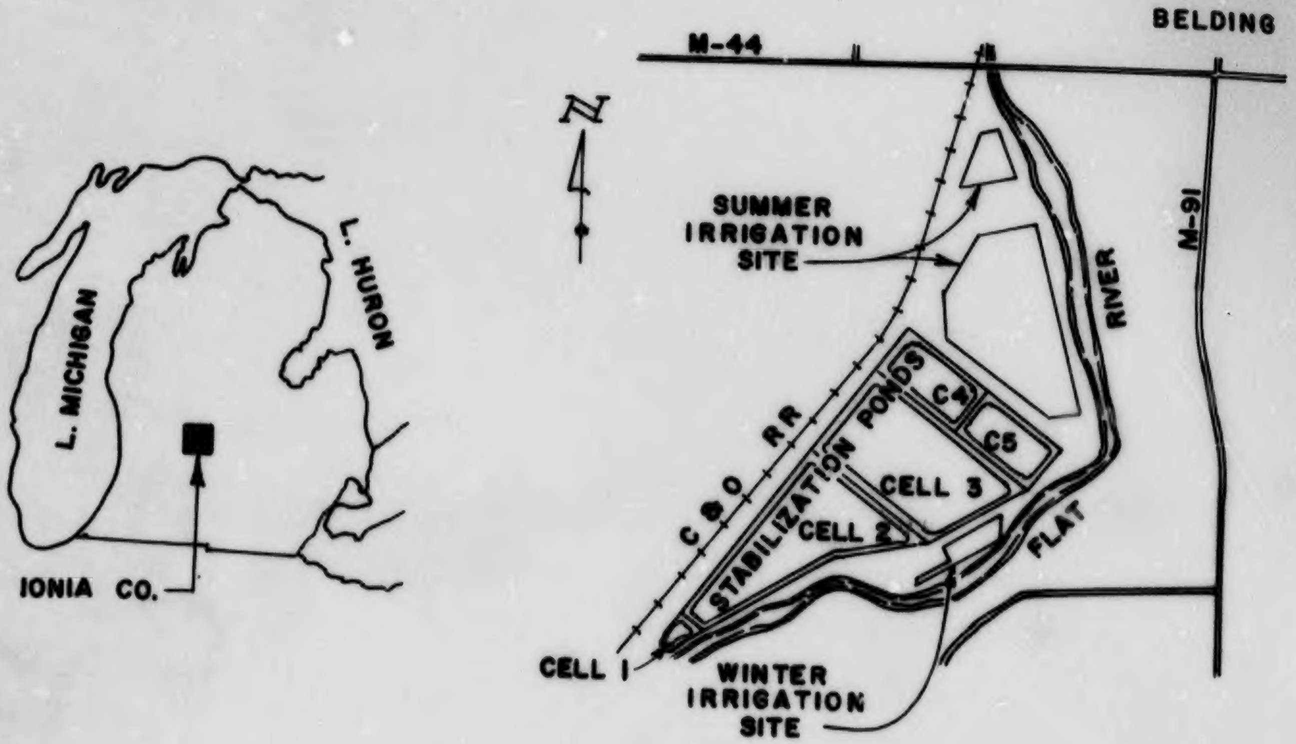
L. MICHIGAN
L. HURON
IONIA CO.
N
M-44
BELDING
M-91
SUMMER
IRRIGATION
SITE
RIVER
FLAT
C & O RR
STABILIZATION PONDS
C4
C5
CELL 3
CELL 2
CELL I
WINTER
IRRIGATION
SITE

Figure 1. Map showing location of project.

These cells were designed to operate in series on a flow-through basis at either of two water levels. The first cell is an anaerobic cell designed for a detention time of three days if operated at the low level and of six days if operated at the maximum level. The remaining four cells were designed as facultative aerobic cells. Facilities were provided so that the effluent would be chlorinated before being discharged into the Flat River.

The Michigan Department of Natural Resources requires annual or semi-annual discharge of stabilization ponds in the spring and/or fall. The facility has not, therefore, been operated on a flow-through basis, but rather on a batch treatment scheme with nominal semi-annual discharge. Excessive water has required discharge of several hectare-meters one or two times in winter and early spring.

Design and construction of the pond system met Michigan Department of Public Health standards when constructed in 1965. Maintenance includes embankment erosion control and regular mowing of grassed areas.

CHEMICAL ASPECTS

Chemical sampling and analysis of the five cells was carried out for the purpose of obtaining background information on the wastewater quality and to learn more about the pond processes. The most detailed data were collected during April, 1972, through March, 1973, when samples were regularly taken from all five cells. These data are presented to compare changes in chemical constituent concentrations as the wastewater moves from influent through cell 5. Chemical sampling during the other years was done primarily of the influent to the ponds and of the effluent from cell 5. The results of chemical testing during the irrigation seasons of 1975 and 1976 are presented in Appendix A for a comparison of chemical changes during the past three or four years and to indicate chemical concentration levels in the effluent irrigated.

Cells ordinarily were sampled by taking a random grab volume of water near the outlet overflow structure of each one. After July 12, 1973, each sample from cell 5 was taken by a composite sampler at the V-notch outlet after chlorination. Thus, the quality of water in cell 5 was the same as that being irrigated.

During most of the 1972-1973 report year, sampling was done on a five-day interval schedule. The program of pond sampling was abbreviated somewhat during the winter season since a reduced level of biological activity and, consequently, a reduction in the rate of change of pond chemical quality was anticipated. Ordinarily, sampling in the winter was on a one or two-week basis. In Appendix B are five years of meteorological data from the site, including precipitation and daily temperature range.

pH

Throughout the entire 1972-73 test period and at all test locations, the pH values were in the weakly acid to moderately alkaline range (Table 2). The lowest pH value of 6.7 was recorded during February and March of 1973,

TABLE 2. SEWAGE OXIDATION PONDS, 1972 AND 1973

pH

Source Date	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	7.2	7.4	7.4	7.7	7.7	7.8
4/29/72	7.1	7.3	7.6	8.0	8.5	8.7
5/4/72	7.4	7.3	8.3	7.9	8.6	8.9
6/16/72	7.4	7.3	7.8	7.8	8.2	8.1
6/21/72	7.5	7.7	8.0	7.9	8.1	8.0
6/26/72	6.8	7.2	7.9	7.8	7.7	7.7
6/30/72	6.9	7.2	8.0	7.7	7.6	7.7
7/6/72	7.1	7.2	8.4	7.9	7.7	7.9
7/11/72	7.8	7.6	8.6	9.2	8.1	8.8
7/17/72	7.1	7.3	7.9	8.4	7.8	8.3
7/21/72	7.1	7.3	8.6	8.6	8.0	8.6
7/26/72	7.2	7.4	8.1	8.1	7.9	8.6
7/31/72	7.2	7.4	8.8	8.4	7.9	8.8
8/5/72	7.2	7.3	8.3	8.7	8.4	9.0
8/15/72	7.3	7.4	7.7	8.3	8.3	8.7
8/21/72	7.8	7.5	8.6	8.4	8.7	9.0
8/25/72	7.1	7.4	8.1	7.4	8.0	8.4
8/30/72	7.4	7.3	9.4	9.2	9.8	9.0
9/4/72	7.4	7.4	8.6	8.6	8.7	9.1
9/9/72	7.2	7.3	7.7	7.8	8.3	8.1
9/14/72	7.3	7.3	7.8	7.7	9.5	8.3
9/19/72	7.4	7.3	7.9	8.1	8.5	8.7
9/25/72	7.3	7.3	8.0	7.5	8.5	8.4
9/29/72	7.3	7.3	8.0	7.8	8.7	8.6
10/9/72	7.6	7.4	8.1	7.8	8.4	7.3
10/14/72	7.3	7.4	8.0	7.6	7.8	8.0
10/19/72	7.5	7.3	7.7	7.7	7.6	7.8
10/25/72	7.2	7.2	7.4	7.8	6.9	7.7
10/30/72	7.2	6.9	7.2	7.4	7.5	7.7
11/30/72	7.0	*				
12/7/72	7.0					
12/14/72	7.0					
12/21/72	7.3					
12/29/72	7.3					
1/5/73	7.3					
1/11/73	7.5					
1/18/73	7.1	7.1	7.2	7.3	7.3	7.5
1/25/73	7.0					
1/31/73	6.9	7.1	7.1	7.2	7.1	7.4
2/19/73	6.8	7.3	7.2	7.5	7.6	7.7
2/28/73	6.7	6.9	6.7	7.0	7.1	7.7
3/13/73	6.7	7.0	7.2	8.0	7.8	7.4

* No entry means no measurement was made

in the influent wastewater and during February in cell 2. The highest value (9.8) was measured in cell 4 at the end of August, 1972.

The pH of the influent and of cell 1 remained in a rather narrow range of 6.7 to 7.8 throughout the year. Photosynthetic activity during the summer, however, produced much higher values of pH in cells 2 through 5. These pH values fluctuated extensively, but during July, August and September were frequently in the 8.5 to over 9.0 range. Under ideal conditions in nutrient enriched water, blue-green algae have the ability to increase pH levels very rapidly to values even above these.

All pH values of both influent and effluent for the summers of 1975 and 1976 (Appendix A) remained within the range recorded during the 1972-73 test period. Thus, for this parameter, no change has occurred during the five years of testing.

Dissolved Oxygen

Dissolved oxygen values during the 1972-73 test period ranged from 0.0 to 29.4 milligrams per liter (mg/l) (Table 3). There was no dissolved oxygen detected in the influent at any time during the year. Anaerobic cell 1 also had no dissolved oxygen most of the year, but values up to 1.1 mg/l were recorded on several occasions.

Photosynthesis seemed to affect the values of dissolved oxygen in all months recorded. The higher values occurred during the summer months of July, August, and September. The highest value of 29.4 mg/l was measured in cell 2 on August 30, 1972.

During the winter, cell 5 had dissolved oxygen values in excess of 6 mg/l, even under ice cover. From January through April, cells 4, 3, and 2 contained progressively lower concentrations of dissolved oxygen than cell 5. No dissolved oxygen measurements were taken during 1975 and 1976.

Suspended Solids

A great variation in suspended solids was obtained at all sampling points throughout the year (Table 4). The greatest variation occurred in the influent which ranged from 3 to over 700 mg/l during the 1972-73 test period. Variation should be expected in the influent, however, since it contains storm water as mentioned earlier.

During the summer months, a decrease in suspended solids through the pond system was apparent with values nearly always greater than 25 mg/l in cell 1 and nearly always less than 25 mg/l in cell 5. In July, suspended solids exceeding 100 mg/l were determined for cells 1, 2 and 3. Large algae populations were likely the cause of the high values in these cells.

Suspended solids values during the months of January through April were similar in all cells. They varied from cell to cell and throughout the time period, but generally ranged between 15 and 50 mg/l. Photosynthetic activity

TABLE 3. SEWAGE OXIDATION PONDS, 1972 AND 1973 - DISSOLVED OXYGEN (mg/l)

Pond Date	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	0.0	0.0	0.0	4.2	4.4	7.3
4/14/72	0.0	0.0	1.5	1.5	3.7	9.0
4/19/72	0.0	0.0	0.0	8.4	8.9	13.4
4/29/72	0.0	0.0	2.0	19.7	15.8	22.0
5/4/72	0.0	1.1	16.0	4.3	12.0	4.1
5/9/72	0.0	0.7	8.8	7.7	9.2	10.2
5/19/72	0.0	0.5	1.2	21.5	19.3	20.8
6/16/72	0.0	0.0	2.9	2.1	3.2	4.3
6/21/72	0.0	0.2	2.9	2.3	2.7	3.9
6/26/72	0.0	0.0	8.15	1.2	2.1	3.6
6/30/72	0.0	0.0	2.4	2.0	2.0	3.7
7/6/72	0.0	0.0	8.0	2.3	1.5	4.7
7/11/72	0.0	0.0	4.0	14.9	2.0	9.8
7/17/72	0.0	0.0	7.1	14.0	1.8	8.9
7/21/72	0.0	0.0	27.8	11.2	5.0	10.8
7/26/72	0.0	0.0	0.9	2.6	1.7	7.5
7/31/72	0.0	0.0	13.7	4.2	3.7	10.2
8/5/72	0.0	0.0	6.2	9.9	10.8	10.3
8/15/72	0.0	0.0	0.0	4.0	5.7	5.9
8/21/72	0.0	0.0	5.2	1.6	11.3	9.1
8/25/72	0.0	0.0	1.1	0.2	4.9	4.4
8/30/72	0.0	0.0	29.4	18.8	20.9	8.1
9/4/72	0.0	0.0	12.7	10.3	23.9	11.4
9/9/72	0.0	0.0	1.0	2.4	4.4	4.0
9/14/72	0.0	0.0	5.4	2.1	21.8	7.4
9/19/72	0.0	0.0	1.7	10.9	5.3	9.7
9/25/72	0.0	0.0	6.7	0.3	8.6	7.9
9/29/72	0.0	0.0	6.7	1.0	16.9	7.6
10/9/72	0.0	0.0	8.0	3.2	11.9	7.0
10/14/72	0.0	0.0	3.85	1.0	2.7	7.35
10/19/72	0.0	0.0	2.6	4.1	3.6	9.3
10/25/72	0.0	0.0	2.7	4.25	0.4	7.7
10/30/72	0.0	0.4	2.0	4.2	6.8	9.9
11/15/72	0.0	0.0	10.1	8.2	10.7	12.7
1/18/73	0.0	0.8	0.8	7.8	3.3	10.9
1/31/73	0.0	0.4	1.0	2.0	2.1	7.3
2/19/73	0.0	0.3	0.0	0.2	0.9	9.1
2/28/73	0.0	0.0	0.0	2.4	0.7	6.3
3/6/73	0.0	0.5	0.8	4.5	7.0	9.6

TABLE 4. SEWAGE OXIDATION PONDS, 1972 AND 1973 - SUSPENDED SOLIDS (mg/1)

Pond / Date	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	3	24	12	21	21	17
4/14/72	10	29	14	33	48	19
4/19/72	31	24	12	35	35	29
4/29/72	61	22	21	43	62	60
5/4/72	29	43	57	29	38	41
5/9/72	27	38	32	6	22	9
5/19/72	16	45	11	26	32	24
6/16/72	25	39	46	11	8	3
6/21/72	33	69	31	4	1	4
6/26/72	45	41	63	11	2	10
7/6/72	53	129	6	7	42	13
7/11/72	47	98	68	112	1	20
7/17/72	19	60	78	16	3	4
7/21/72	121	76	146	31	17	22
7/26/72	71	56	38	5	15	10
7/31/72	41	20	104	1	8	1
8/5/72	27	4	10	26	4	2
8/15/72	39	26	53	35	2	13
8/21/72	33	56	88	99	7	33
8/25/72	23	34	51	94	7	6
8/30/72	97	23	84	51	19	3
9/4/72	64	30	16	13	38	6
9/9/72	10	29	21	25	14	6
9/14/72	121	25	20	11	28	22
9/19/72	85	28	4	11	2	12
9/25/72	202	46	25	34	23	32
9/29/72	748	41	48	17	19	14
10/9/72	24	46	63	12	33	13
10/14/72	54	24	22	31	53	1.0
10/19/72	206	34	34	9	23	2
10/25/72	32	31	51	17	89	2
10/30/72	46	18	11	9	15	8
11/30/72	55					
12/7/72	28					
12/14/72	83					
12/21/72	49					
12/29/72	15					
1/5/73	64					
1/11/73	41					
1/18/73	77	18	31	29	38	11
1/25/73	31					
1/31/73	72	13.5	11	22	6	33
2/19/73	144	18	13	33	27	25
2/28/73	130	28	13	32	29	19
3/16/73	70	21	22	52	50	20

was less intense and algae populations were lower and more sporadic during the winter months. Suspended solids data taken during 1975 and 1976 (Appendix A) are similar to those of the 1972-73 period.

Ammonia Nitrogen

During July, August and September, 1972 (Table 5), ammonia nitrogen concentrations in cell 1 were usually greater than 20 mg/l and in cell 5 they were generally lower than 1 mg/l with a somewhat systematic decrease through cells 2, 3 and 4. In the winter of 1972-73, cell 1 values averaged 17, while those in cell 5 averaged about 15 mg/l, which is a reduction of only about 30 percent.

Influent ammonia nitrogen (Table 5 and Appendix A) for all three midsummers ranged from 9 to 30 mg/l; whereas in the effluent, it ranged from about 0.02 to 0.6 mg/l during July, August and September. In addition, during May and June of 1972, effluent ammonia nitrogen values dropped steadily from 8.0 to 1.1 mg/l. The decrease of ammonia nitrogen between influent and effluent and the steady drop in effluent ammonia nitrogen as the weather and pond water became warmer probably were due to the tie-up of nitrogen in the organic matter.

Nitrate Nitrogen

Nitrate nitrogen values (Table 6) for cells 1, 2 and 3 in winter were nearly always less than 0.1 mg/l; whereas in the warmer months, they were nearly always greater than 0.1 mg/l. In winter, the first three cells were lower in nitrate than the latter two; however, in summer the reverse was true.

All influent and effluent values (Table 6 and Appendix A) for nitrate nitrogen during the three summer irrigation seasons ranged between approximately 0.1 and 1.0 mg/l. These low values indicate that nitrate nitrogen has little bearing on pond operation during summer and also that very little nitrogen of this available form is added to crops by irrigation from sewage oxidation ponds.

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen concentration values (Table 7) during January, February and March of 1973 for all cells ranged from 6.3 to 22.5 mg/l and contained at least 90 percent ammonia. During May through October of 1975 and 1976 (Appendix A), however, the total Kjeldahl values in cell 5 ranged from about 1 to 4 mg/l and ammonia nearly always comprised less than 20 percent of the total recorded. Thus, most of the effluent TKN is present as organic nitrogen in summer; whereas in winter, the nitrogen tends to remain in the ammonia form.

TABLE 5. SEWAGE OXIDATION PONDS, 1972 AND 1973 - AMMONIA NITROGEN (mg/l)

Pond Date	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	5.7	17.0	20	14	19	19
4/14/72	9	21	22	20	18	17
4/19/72	15.5	12.5	16	15	14.5	13
4/29/72	24.3	19	16.5	13	15.5	13.5
5/4/72	8.2	15.5	11.5	11.8	10.5	8.0
5/9/72	18.5	18.5	12	11	9	6.8
6/16/72	9.8	16.0	9.0	4.5	1.0	2.0
6/21/72	34.6	31.6	13.2	7.4	1.1	1.1
6/26/72	23.4	23.1	9.6	5.3	2.0	1.1
6/30/72	18.5	14.2	6.3	3.8	1.1	1.1
7/6/76	27.3	24.9	7.7	4.3	2.95	0.6
7/11/72	16	23.1	7.7	0.6	3.0	0.4
7/17/72	11.7	19.5	7.7	0.3	3.2	0.3
7/21/72	34.6	27.3	2.7	0.4	0.6	0.5
7/26/72	31.6	18.5	6.3	0.38	0.98	0.32
7/31/72	32.2	29.1	5.0	0.25	0.3	0.22
8/5/72	31.6	30.9	8.8	0.32	0.30	0.27
8/15/72	26.7	24.9	13.2	0.43	0.32	0.48
8/21/72	23.7	23.1	6.9	0.38	0.32	0.32
8/25/72	5.3	20	8	1.63	0.30	0.27
8/30/72	16.9	15.8	3.2	0.5	0.3	0.27
9/4/72	32.2	20	7.4	0.64	0.3	0.32
9/9/72	19.5	20	8	1.42	0.25	0.22
9/14/72	15.8	21	9.0	2.24	0.32	0.22
9/19/72	21	18	10.1	1.53	0.27	0.27
9/25/72	14.2	27.3	9.9	2.67	0.27	0.25
9/29/72	28.5	23.1	10.4	4.19	0.38	0.32
10/9/72	18	37	10.6	4.8	0.8	0.85
10/14/72	33.4	31.6	10.1	5.2	2.3	1.8
10/19/72	52.5	39.4	17.4	5.3	3.4	1.69
10/25/72	1.88	20	13.2	0.9	5.1	3.46
10/30/72	23.7	21.8	14.2	6.4	7.0	3.64
11/15/72	17.4	19	13.2	7.04	5.22	1.53
11/30/72	25.5	*				
12/7/72	24.3					
12/14/72	30.3					
12/21/72	19.5					
12/29/72	12.7					
1/5/73	14.8					
1/11/73	20					
1/18/73	12.5	14.8	14.2	5.1	8.12	5.96
1/25/73	16.3					
1/31/73	32.2	18.5	14.8	15.8	15.5	14.5
1/19/73	28.5	19.5	15.3	11.7	10.1	9.8
2/28/73	32.2	21.2	17.4	12.7	11.7	10.4
3/16/73	12.2	9.6	13.2	11.1	10.3	9.6

TABLE 6. SEWAGE OXIDATION PONDS, 1972 AND 1973 - NITRATE NITROGEN (mg/l)

Date \ Pond	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	1.45	0.10	0.10	0.14	0.14	0.16
4/14/72	1.65	0.10	0.08	0.10	0.12	0.20
4/29/72	0.31	0.08	0.1	0.3	0.22	0.3
5/4/72	1.0	0.12	0.33	0.14	0.15	0.14
5/9/72	0.49	0.06	0.2	0.08	0.02	0.12
6/16/72	0.85	0.15	0.2	0.05	0.10	0.10
6/21/72	0.06	0.19	0.13	0.06	0.09	0.09
6/26/72	0.09	0.16	0.25	0.06	0.03	0.06
6/30/72	0.08	0.47	0.33	0.2	0.13	0.16
7/6/72	0.06	0.25	0.3	0.16	0.06	0.11
7/11/72	0.06	0.42	0.3	0.38	0.13	0.22
7/17/72	0.19	0.35	0.25	0.38	0.06	0.13
7/21/72	0.16	0.2	0.44	0.51	0.19	0.08
7/26/72	0.09	0.19	0.13	0.24	0.13	0.01
7/31/72	0.07	0.35	0.59	0.16	0.13	0.03
8/5/72	0.05	0.22	0.11	0.16	0.13	0.05
8/15/72	0.075	0.175	0.25	0.16	0.13	0.045
8/21/72	0.03	0.25	0.25	0.16	0.03	0.03
8/25/72	1.26	0.175	0.21	0.15	0.05	0.07
8/30/72	0.15	0.11	0.31	1.1	0.04	0.03
9/4/72	0.09	0.09	0.19	0.13	0.03	0.03
9/9/72	0.06	0.15	0.18	0.16	0.09	0.06
9/14/72	0.25	0.15	0.19	0.11	0.11	0.06
9/19/72	0.22	0.15	0.13	0.25	0.16	0.06
9/25/72	0.37	0.11	0.18	0.09	0.05	0.03
9/29/72	0.95	0.16	0.16	0.06	0.25	0.06
10/9/72	0.27	0.13	0.25	0.09	1.22	0.17
10/14/72	0.09	0.07	0.17	0.15	0.83	0.38
10/19/72	0.09	0.06	0.06	0.11	0.68	0.77
10/25/72	0.06	0.13	0.16	0.13	0.13	0.38
10/30/72	0.11	0.15	0.09	0.13	0.38	0.94
11/15/72	0.03	0.06	0.09	0.85	1.0	2.03
11/30/72	0.16					
12/7/72	0.09					
12/14/72	0.11					
12/21/72	0.25					
12/29/72	0.53					
1/5/73	0.31					
1/11/73	0.33					
1/18/73	0.09	0.075	0.075	0.06	0.16	0.66
1/25/73	0.05					
1/31/73	0.06	0.06	0.06	0.07	0.07	0.07
2/19/73	0.06	0.045	0.045	0.075	0.11	0.11
2/28/73	0.18	0.06	0.05	0.09	0.09	0.09
3/16/73	0.47	0.09	0.075	0.13	0.145	0.16

TABLE 7. SEWAGE OXIDATION PONDS, 1972 and 1973 - TOTAL KJELDAHL NITROGEN (mg/l)

Date \ Pond	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/04/72	10					
4/14/72	23					
4/29/72	26					
5/04/72	88					
5/09/72	20					
6/16/72	18.3					
10/9/72	14					
12/21/72	23.1					
12/29/72	12.7					
1/05/73	15.0					
1/11/73	21.5					
1/18/73	15.3	15.2	14.8	6.44	8.5	6.3
1/25/73	16.5					
1/31/73	32.7	19.0	15.3	15.8	15.8	14.8
2/19/73	32.8	21.2	15.5	15.3	13	11.5
2/28/73	33.4	22.5	19	14.2	13.5	10.4
3/16/73	17.8	9.9	13.7	12.2	10.4	9.6

The significant reduction of total nitrogen in the effluent compared to the influent is probably due both to degassing of ammonia to the atmosphere and to incorporation of nitrogen in organic material. If the latter mechanism is important, some organic material must settle out and remain in the cell bottoms. Unfortunately, most of the nitrogen that is removed from the cells is discharged into the river in winter rather than irrigated on the crops in summer. More research in this area is needed if maximum use of wastewater nitrogen is to be made as a nutrient for crops.

Orthophosphorus

Influent orthophosphorus concentrations (Table 8) ranged from 1.1 to 17.8 mg/l. These concentration values during the summer months of 1972 decreased as the wastewater moved through the pond system. Generally, cell 1 had values less than 10 mg/l, cell 2 less than 5 mg/l, cell 3 less than 4 mg/l, cell 4 less than 3.5 mg/l, and cell 5 less than 2.5 mg/l. The winter values of orthophosphorus were somewhat similar in all cells, averaging around 5 mg/l. These data indicate that little phosphorus is being applied to the crops in summer and that much phosphorus may be discharged to the stream when drawing down the pond system.

For the 1972, 1975 and 1976 irrigation seasons, influent concentrations of orthophosphorus (Table 8 and Appendix A) were similar but quite varied. The effluent concentrations of orthophosphorus for 1975 were somewhat lower than those of 1972, with about 50 percent of the values less than 1 mg/l.

TABLE 8. SEWAGE OXIDATION PONDS, 1972 AND 1973
ORTHOPHOSPHORUS (mg/l)

Date \ Pond	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	1.2					
4/14/72	1.1	5.9	5.5	6.0	6.0	5.5
4/19/72	5.8					
4/29/72	6.1					
5/4/72	1.3					
6/16/72	2.2					
6/26/72	4.0	6.8	4.0	3.1	4.0	2.6
6/30/72	3.8	7.7	3.75	3.1	4.7	3.1
7/6/72	3.5	5.5	1.9	1.7	2.6	1.8
7/11/72	4.4	9.6	4.2	2.3	3.7	2.8
7/17/72	2.5	9.25	5.88	2.75	4.88	3.5
7/21/72	10	7.8	1.6	2.0	3.4	2.3
7/26/72	9.5	6.6	3.5	2.6	2.8	1.5
7/31/72	5.2	7.3	1.6	2.4	2.7	1.5
8/5/72	4.6	9.2	4.6	2.8	2.3	1.4
8/15/72	4.5	8.6	7.3	3.1	2.6	1.9
8/21/72	3.9	6.3	2.8	2.9	2.1	1.6
8/25/72	1.13	5.6	3.3	4.6	2.6	1.6
8/30/72	5.6	4.8	1.8	1.7	0.8	1.6
9/4/72	5.0	6.7	4.2	3.5	0.6	1.6
9/9/72	4.2	6.2	4.7	3.6	2.6	2.2
9/14/72	7.2	6.2	4.9	3.8	0.2	2.0
9/19/72	7.2	5.7	5.0	3.8	3.2	2.2
9/25/72	6.9	6.2	4.6	3.5	2.4	2.3
9/29/72	6.2	6.4	4.6	3.8	2.1	2.3
10/9/72	2.4	9.4	5.0	3.4	3.3	2.6
10/14/72	6.4	9.6	5.3	3.5	3.0	3.1
10/19/72	11.6	9.6	5.8	2.9	3.4	2.8
10/25/72	14	7.4	5.9	3.0	3.5	2.75
10/30/72	17.8	8.75	6.0	3.4	3.0	3.0
11/15/72	3.25	6.9	5.0	2.75	2.75	2.0
11/30/72	7.4					
12/14/72	10.1					
12/21/72	4.1					
12/29/72	2.2					
1/5/73	4.4					
1/11/73	4.0					
1/18/73	3.8	4.7	4.8	2.4	4.3	3.4
1/25/73	3.9					
1/31/73	7.0	5.0	4.8	5.0	5.0	5.1
2/19/73	11.8	7.2	5.7	5.5	5.6	5.2
2/28/73	6.4	7.5	5.7	5.2	5.5	5.0
3/16/73	3.3	3.4	4.8	4.6	4.8	4.6

However, the 1976 effluent values of orthophosphorus were somewhat higer than those of 1972, with the three July values ranging from 4.5 to 5.2 mg/l.

Total Phosphorus

Time and spacial concentration values of total phosphorus (Table 9) were similar to those for dissolved orthophosphorus. Generally, the total phosphorus values ranged from 2 to 30 percent greater than orthophosphorus. Influent total phosphorus during the irrigation seasons of 1972, 1973 and 1976 (Table 9 and Appendix A) ranged from 1 to 14 mg/l. The total phosphorus concentration values of the effluent for 1975 were lower than for 1972 while those for 1976 were higher than for 1972.

In cells 2 and 3, larger differences in total phosphorus minus orthophosphorus tend to correlate with higher values of suspended solids in the hotter months. Since cells 2 and 3 are the most productive of algae, it can be inferred that the high suspended solids were algae which tied-up notable amounts of phosphorus and produced the disparity in ortho- and total phosphorus values.

A comparison of ortho- and total phosphorus data indicates that most of the phosphorus in both influent and effluent for all three years was in the dissolved orthophosphorus form, that phosphorus reduction through the pond system was 90 to 95 percent during the summer months, and that slightly better removal of phosphorus occurred in 1975 than in 1972. Associated data indicate very little phosphorus reduction during the winter months. These data infer a reasonable amount of phosphorus is precipitated and tied-up in the pond bottom. The 1976 effluent phosphorus levels, however, were appreciably higher than in 1972. This indicates not as much phosphorus staying in the pond bottom and perhaps that the phosphorus adsorption capacity of the pond bottom surface soils may be diminishing. It would be of value in estimating pond life for reasonable phosphorus tie-up to continue monitoring phosphorus levels and perhaps to determine these levels in all 5 cells.

BOD

No biological oxygen demand (BOD) data were taken in 1972; however, great variation of both influent and effluent BOD occurred in 1975 and 1976 (Appendix A), which may be typical of all years. The influent BOD ranged from 24 to 260 mg/l while the effluent BOD ranged from 0.7 to 19.6 mg/l. Thus, the five-cell stabilization pond system did an excellent job of reducing BOD, usually reducing it well over one order of magnitude and averaging about 95 percent reduction.

TABLE 9. SEWAGE OXIDATION PONDS, 1972 AND 1973 - TOTAL PHOSPHORUS (mg/l)

Pond Date	Influent	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
4/4/72	1.4	5.5	5.8	6.3	6.5	8.2
4/14/72	1.25	6.0	5.5	6.4	6.5	6.9
4/19/72	6.0	4.5	5.5	6.3	5.7	5.7
4/29/72	6.75	5.75	5.5	3.75	4.45	4.1
5/4/72	1.39	5.8	5.15	4.45	3.5	2.26
5/9/72	3.9	5.9	4.5	3.8	3.3	1.9
5/19/72	2.7	6.3	4.0	2.8	2.6	1.3
6/16/72	2.75	6.88	4.25	3.0	2.8	3.0
6/21/72	4.13	7.13	5.0	3.38	3.75	3.0
6/26/72	5.5	8.9	5.8	4.1	4.8	3.0
6/30/72	5.5	8.13	3.88	3.69	5.0	3.5
7/6/72	6.5	10.1	4.13	2.88	4.38	3.0
7/11/72	5.3	11.6	4.4	2.75	3.75	2.8
7/17/72	2.75	9.25	5.9	2.88	4.7	3.6
7/21/72	12.5	9.9	3.0	2.5	4.4	2.9
7/26/72	11	8.9	4.4	2.9	3.1	1.9
7/31/72	6.4	9.5	3.75	2.75	3.0	1.7
8/5/72	5.0	9.25	5.0	2.8	2.5	1.4
8/15/72	5.6	9.7	8.1	3.25	2.75	2.0
8/21/72	5.0	7.3	3.9	3.7	2.3	1.75
8/25/72	1.13	5.6	3.9	4.9	2.6	1.75
8/30/72	8.8	5.3	3.1	2.5	1.1	1.9
9/4/72	6.3	7.0	5.0	4.0	1.1	2.0
9/9/72	5.4	7.3	5.5	4.1	3	2.5
9/14/72	8.75	6.9	5.6	4.25	0.75	2.5
9/19/72	9.25	6.5	6.0	4.25	3.25	2.62
9/25/72	7.4	7.1	5.3	5.5	2.9	2.75
9/29/72	7.5	7.1	5.25	3.9	2.4	2.4
10/9/72	2.62	9.5	5.25	3.5	3.55	3.1
10/14/72	7.25	10.5	5.75	4.0	3.5	3.25
10/19/72	13.9	11.4	7.0	3.9	4.4	3.2
10/25/72	14	7.4	5.9	3.0	3.5	2.75
10/30/72	17.8	8.75	6.0	3.4	3.0	3.0
11/15/72	3.25	6.9	5.0	2.75	2.75	2.0
11/30/72	7.4					
12/7/72	6.9					
12/14/72	10.1					
12/21/72	4.75					
12/29/72	2.5					
1/5/73	4.75					
1/11/73	4.4					
1/18/73	4.7	5.0	5.5	2.6	4.4	3.6
1/25/73	4.4					
1/31/73	8.0	5.2	5.1	5.6	5.2	5.6
2/19/73	14.2	8.0	5.75	5.5	5.65	5.2
2/28/73	7.9	7.5	6.0	5.75	5.9	5.2
3/15/73	4.4	4.25	5.75	5.6	5.5	5.25

Chloride

Chloride concentrations of both the influent and effluent for 1975 and 1976 are listed in Appendix A. The effluent values ranged between 110 and 165 mg/l, while the influent concentrations were somewhat more varied, ranging between 35 and 340 mg/l. The 35 mg/l value probably was the result of dilution by runoff from precipitation, whereas the 340 mg/l concentration probably occurred due to salting of highways. The chloride concentration levels of the effluent serve well as a means of tracing the irrigated wastewater, as described in later sections.

SECTION 5

DEVELOPMENT OF DESIGN PARAMETERS

Development of design parameters for full-scale wastewater irrigation operations under northern climates and in areas where the soil is primarily glacial drift is considered under this section. Site characteristics, monitoring procedures, and irrigation system design factors relative to the summer site only are discussed here, because the winter site studies will be described later. Results obtained to date are included and suggestions for full-scale irrigation systems are discussed.

SITE CHARACTERISTICS

Soil, topography, and drainage characteristics were considered in evaluating the summer site for irrigation. Soils of the 102 mm per week application area (Figure 2) are primarily of the Newaygo sandy loam type, which normally are well drained and moderately well drained soils that formed in sandy loam and loam outwash. The soils usually are droughty with good surface and internal drainage, and on the project site they occur on a broad flat valley plain having a slope of 0 to 2 percent. While most of the 76 mm per week area also is Newaygo sandy loam, the western portion of this area is comprised of the somewhat poorly drained Wasepi series.

The 51 mm per week application area is comprised of a northern and a southern portion. Most of the northern portion of the 51 mm area is composed of well drained and moderately well drained Montcalm soils which usually are of loamy texture and on a gently sloping till plain; however, the eastern end of this portion is composed of poorly drained Glendora soils. The southern one-half of the south portion is composed of Newaygo sandy loam, while the northern one-half of this portion is covered with sandy loam fill material from excavated ditches. Artesian springs emerge in the section between the northern and southern portions. Water from these springs is outletted to the Flat River via ditch 2.

Included within the areas mapped Newaygo and Montcalm, however, are small depressions of more poorly drained soils. Thus, the surface soil and topography were modified somewhat during the installation of the drainage ditches on the south and the west sides, and during the construction of the road along the east side of the site. Sandy loam soil material from the excavated ditches and from land modifications was used to fill in low spots and poorly drained areas. This filling, plus the construction of the drainage ditches and diversions both on the south and the west sides of the irrigation site, was expected to keep the depth of the water table low enough for wastewater irrigation.

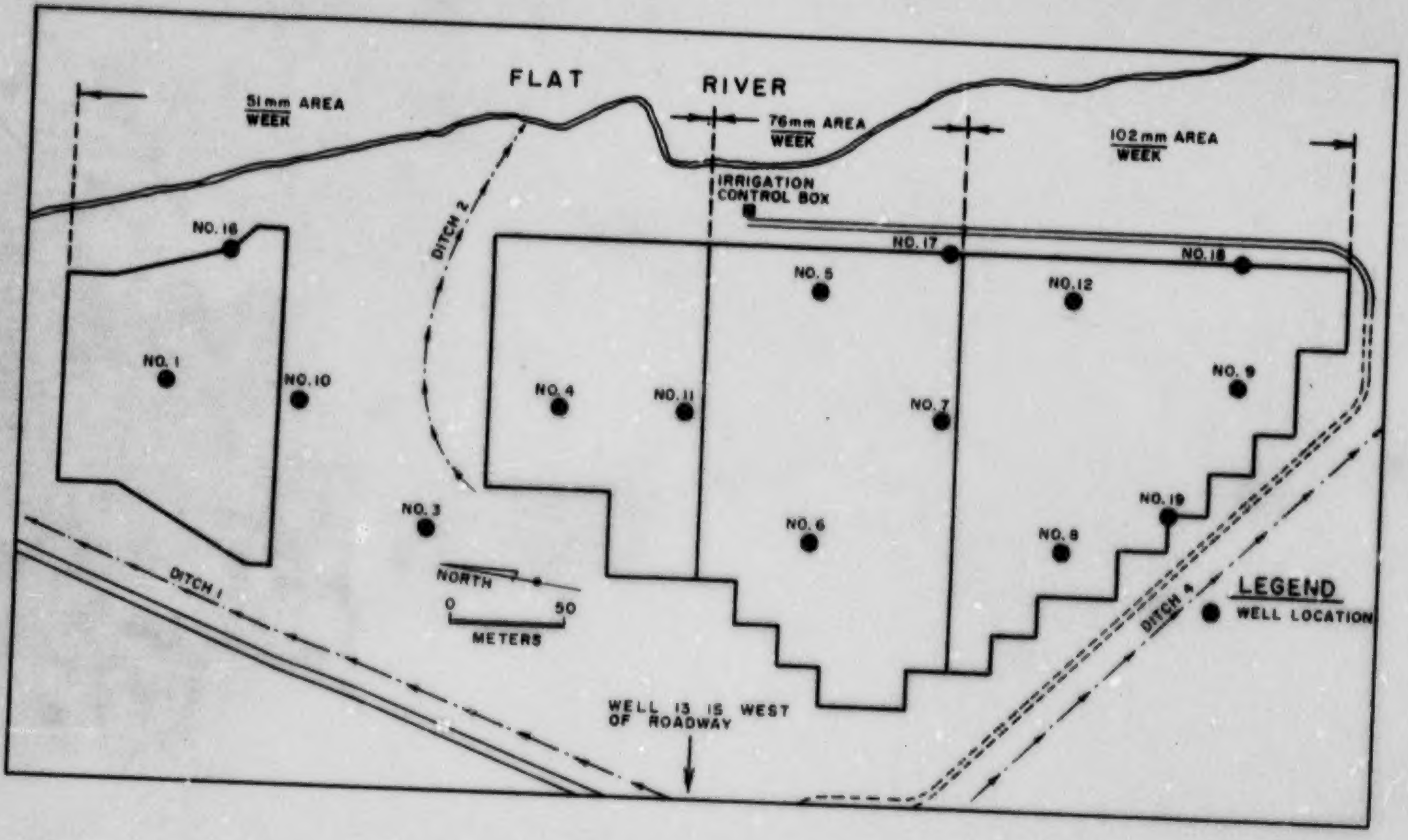
FLAT RIVER
51mm AREA / WEEK
76mm AREA / WEEK
102mm AREA / WEEK
IRRIGATION CONTROL BOX
DITCH 2
NO. 16
NO. 1
NO. 10
NO. 3
NO. 4
NO. 11
NO. 5
NO. 6
NO. 17
NO. 7
NO. 12
NO. 8
NO. 18
NO. 9
NO. 19
DITCH 1
DITCH 4
NORTH
0
50
METERS
WELL 13 IS WEST OF ROADWAY
LEGEND
WELL LOCATION

Figure 2. Summer site showing weekly irrigation application levels, monitoring wells, and surface ditches

After several years of irrigation, it became apparent that both surface and subsurface drainage on parts of this site were not adequate for maximum crop production at the levels of irrigation applied. A high water table and surface run-off caused above-normal tree mortality on certain areas and produced difficulty in harvesting of sod crops on others.

The objective of this portion of the research project was to develop guidelines for installing wastewater irrigation projects on glacial till soils Thus, it was reasonable to use a glacial till soil that was not the best agriculturally, because this type is more readily available, and to apply relatively high application levels per week, because the higher the level one can apply, the less land area required. The seeming inconsistency of the 102 mm per week area showing the least drainage problems and the 51 mm area presenting the greatest, gives the opportunity for some constructive evaluation. The following evaluations and suggestions should be considered in choosing land sites for practical full-scale operations.

County soil surveys made cooperatively by the Soil Conservation Service and the State Agricultural Experiment Station present information which is very helpful in locating appropriate land irrigation sites. It must be remembered, however, that the information presented is for the predominant natural soil conditions and must be interpreted in light of the facility being considered. The Belding project considered these facts but research results emphasized additional soil and drainage aspects when 102 to 204 cm per year of wastewater were added.

The rate at which a soil can transmit water is much more critical with effluent than with agricultural irrigation. In agricultural irrigation essentially all the water is used by the crops while in effluent irrigation up to 80 or 90 percent of the water applied must move from the area. Due to the effects on water transmissibility, soil variations within a mapped classification, soil areas within a classification but too small to be mapped separately, and soil variations outside the actual wastewater irrigation area are very important. Insufficient lateral transmissibility on nearly flat areas causes a high water table, as at Belding, whereas on steeper slopes the water table or perched water table may reach the soil surface causing surface flow.

An additional soil consideration emphasized by the Belding work has to do with disturbed soils, i.e., soils moved from one location to another during the construction phase of the project. These disturbed soils have much poorer drainage characteristics than they had in their original state. The degree of deterioration depends upon their original moisture and clay contents, and on the amount they are worked and compacted. Additional research needs to be conducted to establish design parameters on disturbed soils in order to acquire data for locations where appreciable amounts of earthwork are to be done.

Greater crop damage due to drainage problems occurred on the 51 mm per week than on the 102 mm area at Belding. The difference in drainage problems was due to original soil differences, as well as differences in the amount of disturbed soils. The small area of Glendora soil at the eastern end of the 51 mm per week area remained wet most of the time. This wetness caused direct crop damage and, also, indirect crop damage to the rest of the area since equipment could not turn around at this end of the field and inadequate maintenance occurred. Much of the soil on the southern part of the 51 mm area was fill material from the ditches and was somewhat poorly drained after compaction during placement.

Good surface or subsurface drainage is necessary for land with somewhat limited lateral transmissibility to prevent development of a high water table. If 50 percent of the natural rainfall can be surface drained, the amount of water that must be laterally transmitted will be reduced about 25 percent when 102 cm of wastewater are applied each year. The Belding project has diversions both to the west and to the south of the site to prevent surface runoff from entering the irrigation areas. However, the irrigation areas were not adequately graded during construction to provide sufficient surface drainage of rain and snowmelt from the site.

It is usually possible to improve the lateral transmissibility of water from a site by use of subsurface drains. These drains, however, increase the cost of construction by several hundred to several thousand dollars per acre. This added cost can make the land application alternative non cost-effective.

The project demonstrated that certain naturally wet glacial drift soils can be used for wastewater irrigation because 102 mm per week of effluent were applied very beneficially to certain areas. It emphasized the need for good surface drainage because the primary trouble spots were associated with surface depressions; and it indicated that certain areas should not receive any wastewater because the Glendora soils were naturally too wet for good crop production. Thus, it emphasized the need for very detailed site evaluation relative to possible artificial drainage requirements under the addition of appreciable amounts of wastewater.

Several additional years of research to determine the actual improvement attainable by surface and/or subsurface artificial drainage of parts of the 52 and 76 mm per week areas would have been helpful in establishing more specific drainage design parameters for the North Central Region.

MONITORING PROCESS

Monitoring systems at Belding include those for determining the quantity and quality of wastewater irrigated and those for determining the quality and movement of liquid from the irrigation site. The quality of water irrigated is the same as that of cell 5, discussed under Section 4, while the quantity applied is considered under irrigation in this section.

Movement of liquid from the summer site has been determined since the project's inception by monitoring the flow which passes specific well locations. During the summers of 1975 and 1976, surface water leaving the

76 and 102 mm per week application level areas also was monitored. The quality of these surface and subsurface flows from the site is presented in Section 7. Only hydrologic research data for the summer site and associated problems are considered under this heading.

There are 15 well locations in the summer irrigation site (Figure 2). Five of the locations each have two wells (Table 10) which permit water quality sampling from two elevation levels. Eighteen of the 20 wells provide water elevation data, while 15 of the 20 are used to provide samples for chemical quality information. Wells 16 through 19 were drilled late in 1974 to provide additional research data for the 1975-76 two-year extension of the project. Elevations of ground level and of top of well casing for each well were reestablished in 1975 (Table 10).

The average ground water elevation rose each year from 1971 through 1974, as shown in Figure 3. From August 1971 to August 1972, the average rise was about 0.4 m, and was due to excess rainfall since this was prior to irrigation of the site. During the year 1972-73 as a result of irrigation and of above-normal precipitation, it rose an additional 1 m average in the 76 and 102 mm application areas. The 1974 levels were slightly above those for 1973 and sufficiently high to cause problems with the growing and harvesting of crops as discussed under Section 6.

Ground water levels on May 19, 1975, near the beginning of irrigation, were somewhat below those when irrigation was begun in May, 1973 (Figure 4). This was due primarily to a lower amount of precipitation in March and April of 1975 and to better established crops which transpired more water than in 1973. By October, 1975, however, the water levels were essentially the same as those of October, 1973. Heavy rains in August and September were the primary cause of water level increase. Water levels of the 102 mm per week area in October, 1973 were lower than in May, 1973; whereas in October, 1975, they were higher than in May, 1975. This merely reflects the fact that more rain fell during the irrigation season of 1975 than during 1973.

The ground water elevations of May 11, 1976, immediately prior to beginning the irrigation season, were very nearly the same as those recorded for May 19, 1975. From May 11 through September 8 the water table lowered an average of 0.3 m due to high evapotranspiration and to low rainfall. In response to heavy rainfall late in September, however, it rose again nearly to the October, 1975 levels. Thus, during the last several years, water levels in the 102 mm per week area ranged around the 0.6 m depth, while the levels in the 76 mm area ranged around the 0.3 m depth, and in the 51 mm area water levels were near the soil surface. This reflects the generally slow water transmissibility rate for the various soils of the summer site.

The general pattern of ground water flow at the summer site is shown in Figures 5 and 6. Flow from the 102 mm per week area is east or southeast to the river or south to ditch 4; flow from the eastern three-fourths of the 76 mm area is east to the river while that from the western one-fourth is south to the 102 mm area; and flow from the 51 mm area is generally eastward to the river or to ditch 2.

TABLE 10. GROUND AND TOP OF CASING ELEVATIONS AND DEPTHS TO TOP OF SCREEN FOR SUMMER SITE MONITORING WELLS

Well number	Application level (mm/wk)	Ground elevation (m)	Top of casing elevation (m)	*Depth to top of screen (m)
1	51	230.80	231.61	2.74
3	-	232.14	233.23	1.62
4E	51	230.20	231.05	7.16
4W	51	230.20	231.05	-
5	76	229.43	230.58	1.68
6	76	231.20	232.50	1.98
7	76	230.34	231.31	2.32
8	102	231.05	231.71	2.74
9E	102	229.99	230.90	8.44
9W	102	229.99	231.01	-
10E	-	231.10	232.33	2.96
10W	-	231.10	232.44	4.42
11E	51	230.29	231.47	2.99
11W	51	230.29	231.32	1.43
12E	102	229.64	230.73	1.98
12W	102	229.64	230.72	3.87
16	51	229.64	230.29	8.84
17	76	229.37	230.26	2.22
18	102	229.22	229.38	1.32
19	102	230.66	231.82	3.74

* Screen lengths are 0.762 m except for wells 8 through 12 which are 0.915 m, and wells 16 through 19 which are 0.610 m.

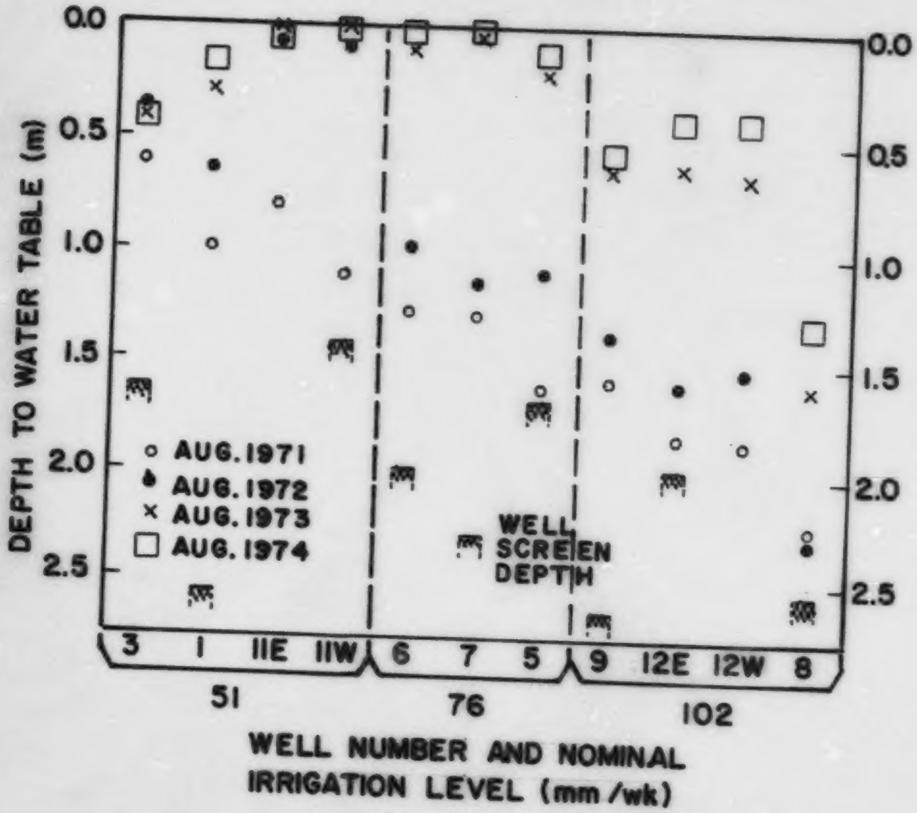

Figure 3. Water table increases under irrigation at summer site.

NOTE: Depth to top of screen for well 11E is 2.99 m and for well 12W is 3.87 m.

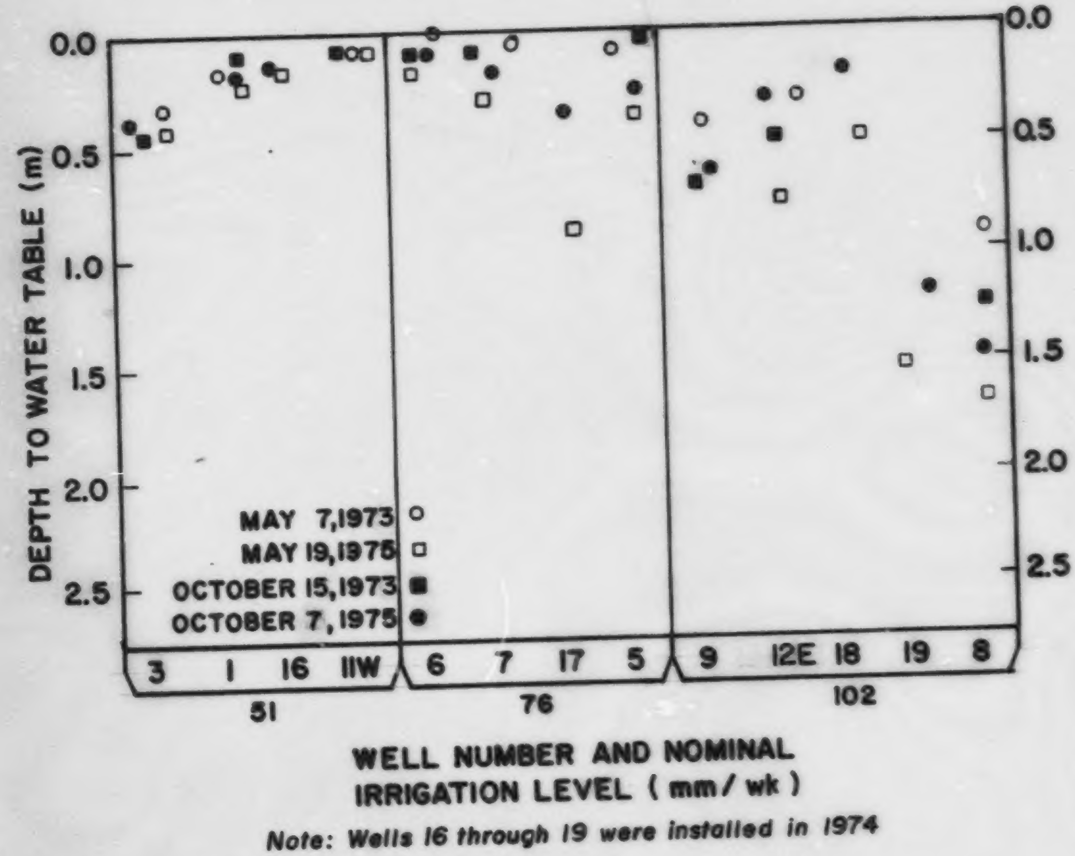

Figure 4. Ground water levels each at the beginning and the end of the irrigation season for both 1973 and 1975.

Summer (July 1974) flows are in the same direction as the fall (October 1975) flows and differ only in that the summer water table is somewhat lower, especially in the better drained 102 mm per week areas. Wells 16 through 19 were installed late in 1974 to help verify the direction of flow and to provide quality information at maximum distances along the demonstrated general ground water flow paths. The flow patterns determined from the 1976 data are essentially identical to those of Figures 5 and 6.

When the ground water level between wells 6 and 7 rises sufficiently to intersect the ground surface, flow occurs over the plots of the 76 mm per week area. Had adequate filling of this low spot and uniform surface grading of the area been achieved, this overland flow would have been somewhat reduced Proper surface drainage also would have prevented any surface flow of the 102 mm area from moving onto the 76 mm area.

Some runoff due to heavy precipitation will occur from most glacial till soils in the North Central Region. The more wastewater one irrigates the greater the amount of runoff one should expect on any specific soil type because of its relatively fixed transmissibility rate. Also, the greater the amount of rainfall trapped and required to infiltrate the greater the amount of wastewater runoff (direct or as interflow) one should expect. Thus, as much natural precipitation as possible should be permitted to flow quickly from a wastewater irrigation area. This will help keep the ground water table down and allow wastewater to infiltrate so that it can be renovated.

IRRIGATION SYSTEMS

The pumping facilities which supply the effluent to the irrigation sites were constructed over the outlet weir box at the end of the chlorine contact chamber. The weir box and chlorine contact chamber together serve as a sump for the pumps. During operation, a small discharge over the weir insures an adequate supply of wastewater to the pumps at all times.

A 3.7 by 5.5 m pumphouse was constructed over the weir box area. This house contains two pumps which are alternated manually, one serving as a standby. Each pump is a vertical turbine pump, designed for an output of 9.5 liters per second (l/s) against a total dynamic head of 53 m and an 11.2-kilowatt (kw), 3-phase electric motor. Following the pumps is an in-line flow meter which measures the amount of effluent pumped.

In the pumphouse are protection devices for the pumps and irrigation systems, and sampling and metering equipment to assure adequate monitoring of the wastewater. An automatic sampler collects and composites samples of pond effluent. The sampler is self-priming and is adjustable to take from 3 to 20 samples per hour. A 90-degree V-notch weir allows measurement of discharge to the Flat River.

A 152 mm diameter header pipe carries the effluent from the pumphouse northward to the summer irrigation areas, while a 102 mm header is used to

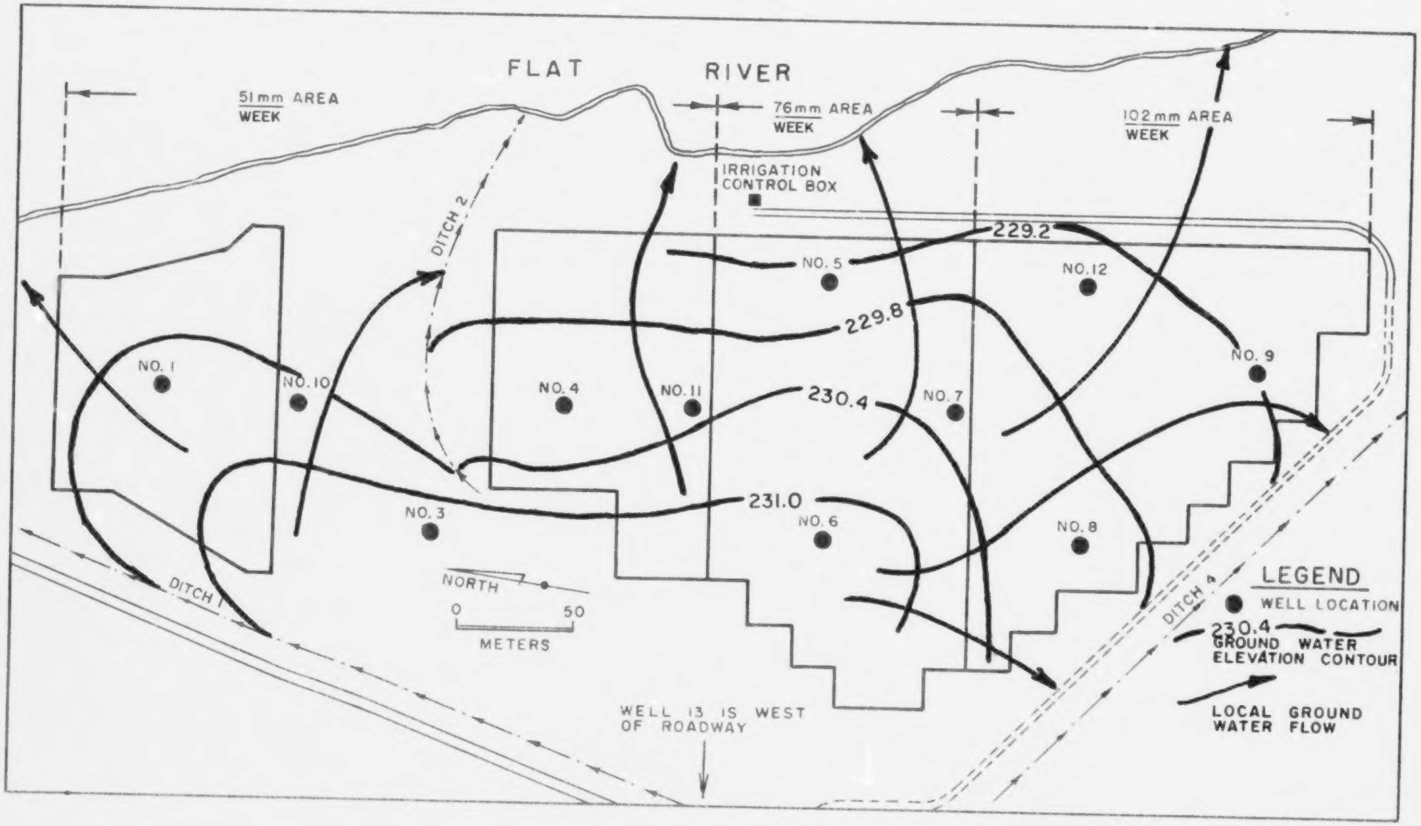
FLAT RIVER
51mm AREA / WEEK
76mm AREA / WEEK
102mm AREA / WEEK
IRRIGATION CONTROL BOX
DITCH 2
DITCH 1
DITCH 4
NO. 1
NO. 10
NO. 3
NO. 4
NO. 11
NO. 5
NO. 6
NO. 7
NO. 12
NO. 9
NO. 8
229.2
229.8
230.4
231.0
NORTH
0 50
METERS
WELL 13 IS WEST OF ROADWAY
LEGEND
WELL LOCATION
230.4 GROUND WATER ELEVATION CONTOUR
LOCAL GROUND WATER FLOW

Figure 5. Summer irrigation site showing ground water setting (July 1974).

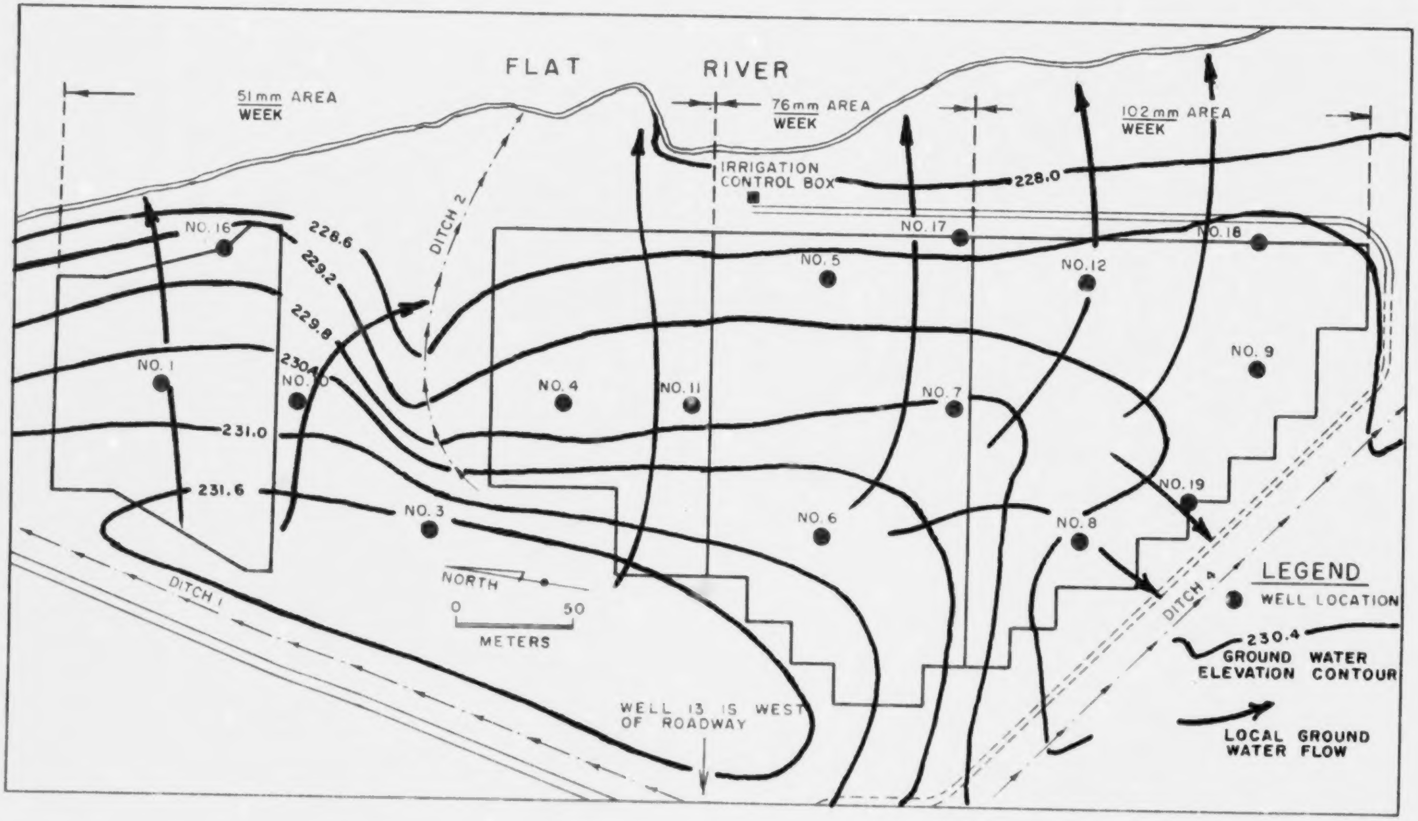
FLAT RIVER
51mm AREA / WEEK
76mm AREA / WEEK
102mm AREA / WEEK
IRRIGATION CONTROL BOX
DITCH 2
DITCH 1
DITCH 4
228.0
228.6
229.2
229.8
230.4
231.0
231.6
NO. 1
NO. 3
NO. 4
NO. 5
NO. 6
NO. 7
NO. 8
NO. 9
NO. 10
NO. 11
NO. 12
NO. 16
NO. 17
NO. 18
NO. 19
NORTH
0 50
METERS
WELL 13 IS WEST OF ROADWAY
LEGEND
WELL LOCATION
230.4 GROUND WATER ELEVATION CONTOUR
LOCAL GROUND WATER FLOW

Figure 6. Summer irrigation site showing ground water setting (October 1975).

transport the effluent southward to the winter irrigation site. All header lines are buried and all have appropriate vents and drains to permit air removal and effluent drainage when necessary. Only the summer site irrigation system will be discussed here, because the winter system will be considered under Section 9.

The summer irrigation system is a solid-set, 18 by 18 m-spaced, buried-pipe arrangement as shown in Figure 7. The laterals are 51 mm diameter PVC pipe laid on grade so that they can be drained during winter. Thermal hydraulic remote control valves automatically regulate the effluent through an electrical control panel to appropriate laterals.

Sprinklers are Rain Bird No. 30WS full circle type with a single 4.4 mm nozzle in each. The sprinklers cover a 29 m diameter area at 380 kPa pressure with a discharge rate of 0.4 l/s. A 0.4 l/s discharge on an 18 by 18 m area gives a precipitation rate of 4.2 mm per hour. Specific irrigation levels are applied by controlling the duration of irrigation on each area. An overview of the summer irrigation site is shown in Figure 8.

Delays and problems nearly always occur during the construction and start-up period of any project. Also, during the normal operation of any irrigation project, adjustments in schedule have to be made for seeding, spraying, harvesting and poor weather conditions. The Belding project was no exception and had its share of delays due to construction and to crop seeding problems during the first two years of operation in 1973 and 1974. In 1973 during May through October, 106,000 m^3 of wastewater were applied; while during July through October 1974, only 72,000 m^3 were irrigated.

Irrigation application levels of 51, 76 and 102 mm per week were recommended for the summer site in the original project proposal. These nominal levels were applied throughout the project to-date, with one half the quantity being applied two times each week. The amount of water actually irrigated during each of the 18 intervals in a specific 162-hour weekly cycle is listed in Table 11. These data also were used to calculate the approximate depth irrigated weekly over each area, as shown in the table. The 102 mm per week area received 92 to 98 percent of the design nominal amount of water, the 76 mm area received from 97 to 110 percent of nominal, while the 51 mm area had the greatest departure from nominal, ranging from 76 percent in the northern portion to 119 percent in the southern portion.

These variations in application levels are slightly larger than normally would be expected in a research project and were due primarily to the individually fabricated automatic valve changing equipment. The individually fabricated timer was time-consuming and somewhat difficult to adjust; however, by the beginning of the 1975-76 two-year project extension, it was operating fairly well.

In 1975 during the early May through mid-October irrigation season, 79,000 m^3 were distributed with only three interruptions. A two-week interruption occurred in late June-early July while waiting for harvesting

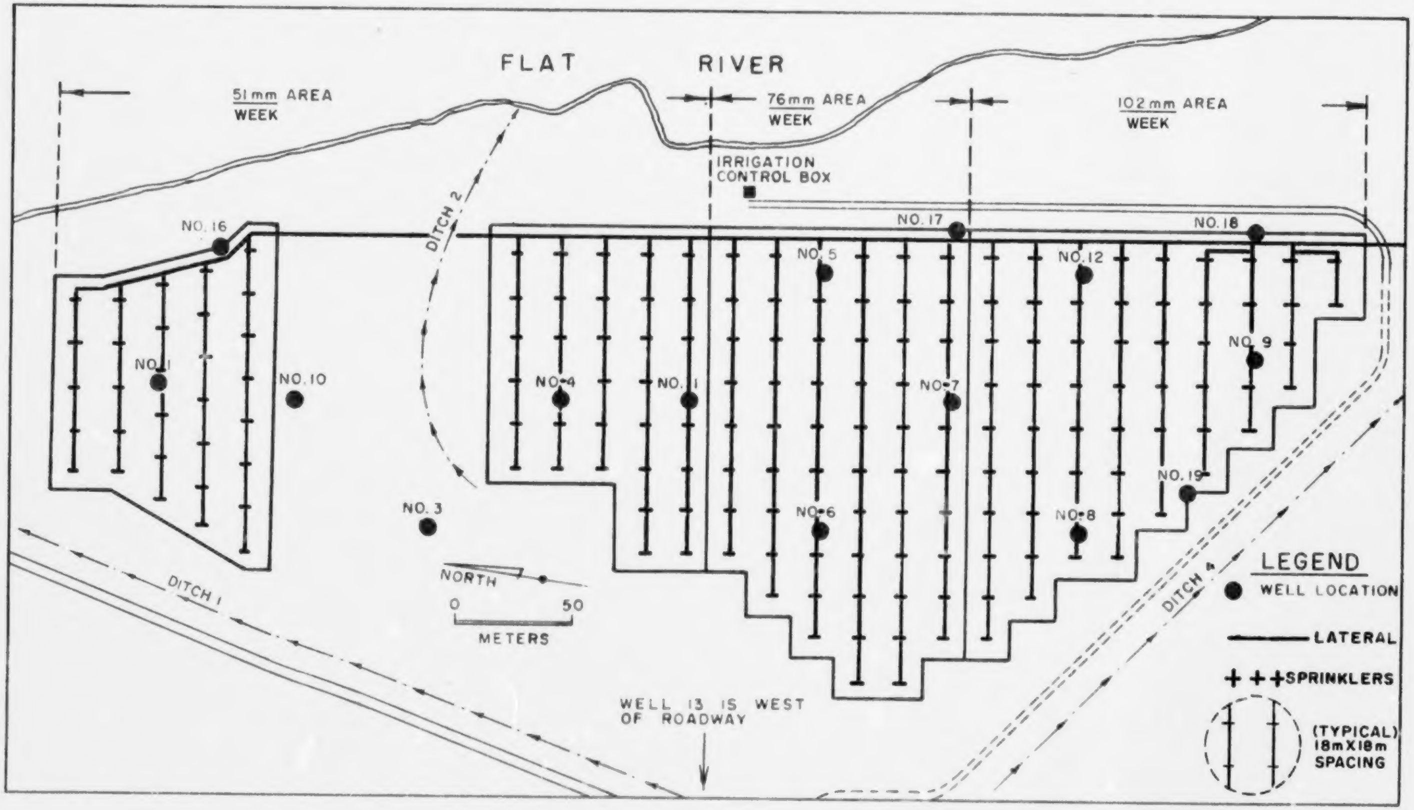
FLAT RIVER
51mm AREA / WEEK
76mm AREA / WEEK
102mm AREA / WEEK
IRRIGATION CONTROL BOX
DITCH 2
DITCH 1
DITCH 4
NO. 16
NO. 11
NO. 10
NO. 3
NO. 4
NO. 1
NO. 5
NO. 6
NO. 17
NO. 7
NO. 12
NO. 8
NO. 18
NO. 9
NO. 19
NORTH
0 50
METERS
WELL 13 IS WEST OF ROADWAY
LEGEND
WELL LOCATION
LATERAL
SPRINKLERS
(TYPICAL) 18m X 18m SPACING

Figure 7. Summer site showing irrigation system layout.

TABLE 11. ACTUAL WEEKLY IRRIGATION
1973
Summer Area

Day	Date	Time[1]	Totalizer[2] Reading (gallons)	Volume Irrigated (m^2)	Valves	Area[3] (m^2)	Area (ha)	In.[4] (mm)	Total[5] (mm)	Nom. Rate (mm)	%[6]
M	10/29	2:30P	38,668,000	272	1,2	5,685	0.57	47.0	94.0	102	92.5
Tu	10/30	2:30A*	28,739,900	300	8,9	7,023	0.70	42.2	84.3	76	110.7
Tu	10/30	12:35P	28,819,100	153	14,15,16	7,692	0.77	19.8	39.6	51	78
Tu	10/30	5:30P*	28,859,600	375	3,4,5	7,692	0.77	48.3	96.5	102	95
W	10/31	5:30A*	28,958,700	261	10,11	7,023	0.70	37.1	74.2	76	97.3
W	10/31	2:20P	29,028,500	206	17,18,19	6,689	0.67	30.2	60.5	51	119.0
W	10/31	8:30P*	29,083,000	323	6,7	6,354	0.66	50.0	100.0	102	98.5
Th	11/1	8:30A	29,168,200	223	12,13	5,685	0.57	38.6	77.2	76	101.3
Th	11/1	5:30P*	29,227,100	151	20,21,22	7,692	0.77	19.3	38.6	51	76.0
Th	11/1	11:30P*	29,266,900	258	1,2	5,685	0.57	44.7	-		
F	11/2	11:30A	29,335,000	212	8,9	7,023	0.70	29.7	-		
F	11/2	8:30P*	29,390,900	169	14,15,16	7,692	0.77	21.8	-		
Sa	11/3	2:30A*	29,435,600	352	3,4,5	7,692	0.77	45.2	-		
Sa	11/3	2:30P	29,528,700	228	10,11	7,023	0.70	32.0	-		
Sa	11/3	11:30P*	29,588,900	183	17,18,19	6,689	0.67	26.9	-		
Su	11/4	5:30A*	29,637,200	316	6,7	6,354	0.66	49.0	-		
Su	11/4	5:30P*	29,720,700	234	12,13	5,685	0.57	40.4	-		
M	11/5	2:30A*	19,782,500	123	20,21,22	7,692	0.77	15.7	-		
M	11/5	8:30A	29,815,100								

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[1] Inferred where asterisked. Non-working hours.

[2] Actual readings at the times indicated. Readings during non-working hours were taken at the times switching of valves was supposed to take place according to the cam settings in the valve control panel.

[3] Number of sprinkler heads x 334.4 m^2/head.

[4] Volume irrigated/10,000 m^3/ha-m/area.

[5] First cycle (Monday through Thursday) valves are doubled; second cycle (Friday through Monday) had irregularities due to low pumping water level, etc.

[6] Percentage of nominal amount of water actually applied.

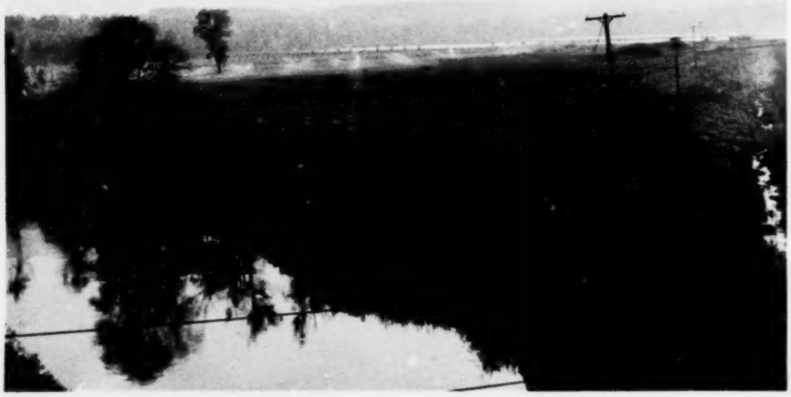

Figure 8. This is an overview of the summer irrigation site, looking south from M-44 bridge over Flat River, which shows sprinklers in the middleground, stabilization ponds in the background and Ditch 1 at the extreme right.

equipment; repairs at the end of July caused a brief shutdown; and heavy rain in early September forced a shutdown after three days of a scheduled week's run. In 1976, about 88,000 m^3 of wastewater were applied to the summer site on the schedule listed in Table 12. The irrigation schedule was interrupted only twice, both in June and in late August-early September for harvesting hay crops.

Hydraulically, the system operated very well during 1975 and 1976. The pumps supplied adequate pressure and the sprinklers provided an excellent distribution pattern. The termal-hydraulic valves all operated well; however, a broken electrical feeder wire to one set of valves caused a problem early in the 1975 season. Since breaks in buried electrical wires are difficult to find and costly to repair, it is recommended that special precautions and care be taken during installation of electrical valving systems. While automatic valve changing equipment can be individually fabricated, it usually is preferable to buy a well-tested commercial model.

All irrigation systems should be designed to provide great flexibility in distributing wastewater over the site. The ability to provide uniform distribution is of primary importance, since renovation usually varies directly with the quality of the distribution. The ability to not irrigate certain

TABLE 12. SUMMER SITE IRRIGATION DURATION AND VOLUME PER WEEK, 1976

Week	Duration (hr)	Volume (gal.)	Volume (m^3)
5/17-24	162	1,556,100	5,890
5/24-31	161.5	1,121,100	4,244
5/31-6/7	157	1,179,000	4,463
6/7-14	40	308,000	1,166
6/14-21	162	1,212,000	4,588
6/21-28	162	1,238,000	4,686
6/28-7/5	161.8	1,258,000	4,762
7/5-12	161.2	1,264,000	4,787
7/12-19	162	1,247,100	4,721
7/19-26	162	1,253,800	4,746
7/26-8/2	162	1,226,400	4,642
8/2-9	161.8	1,175,600	4,450
8/9-16	162	1,183,400	4,480
8/16-23	162	1,185,600	4,488
8/23-30	21	147,800	559
8/30-9/7	-	-	-
9/7-9/13	145.8	1,107,900	4,194
9/13-9/20	162	1,272,600	4,817
9/20-9/27	161.8	1,225,900	4,640
9/27-10/4	162	1,206,300	4,566
10/4-11	161.5	1,213,100	4,592
10/11-15	79	607,600	2,300
	TOTAL	23,189,900	87,781

small areas also is of great value. Field depressions or small areas with high water tables should not be irrigated, especially during times of high amounts of rain. Skipping certain areas can provide better crops in those areas or can permit harvesting a normally wet area with the rest of the field. A solid-set buried system, as installed at Belding, provides the maximum distribution flexibility. This flexibility was not used during the project, however, since it was not part of the experimental design.

A detailed study of all site characteristics of a prospective wastewater irrigation site is valuable to the design of distribution systems. Design of an irrigation system with great distribution flexibility is even of greater value, since it is impossible to determine when and what type of distribution system modifications are required to produce the desired level of renovation. Glacial drift soils usually are quite varied in their drainage characteristics. While certain soils will have adequate natural drainage, most will need to be provided with good surface drainage; in addition, some will require subsurface drainage if 152 to 204 cm of wastewater are to be applied per year.

SECTION 6

USE OF EFFLUENT FOR MUNICIPAL CROPS

The sod and the nursery trees required by a city's Park and Public Works Department usually must be obtained from outside sources at significant cost. Thus, it seemed a worthy objective to demonstrate the use of city wastewater and nutrients for growing crops having direct municipal value. This would function also as a recycling operation with many benefits to the general public.

This section of the report considers only information relating to the sod and the tree operations of the summer irrigation site. It includes a brief description of the major activities to date, but concentrates primarily on the effects of irrigation levels on crop responses and management problems.

SOD FARM

The initial plan suggested irrigation of a forage grass (reed canarygrass), a legume (crown vetch), and an unspecified turf grass under three different levels of wastewater application. These irrigation levels were 51, 76 and 102 mm per week with one half to be applied twice each week.

Artesian springs in the northern portion of the irrigation site, however, caused deviation from the original plans. Approximately 1 ha of low area was abandoned before construction of the irrigation system, but after the monitoring wells were installed. Thus, in February, 1971, after a series of meetings with area soil conservationists and EPA and State agricultural specialists, it was decided to rearrange the research plots and modify somewhat the crops to be irrigated. The original intent of the project, to determine the responses of sod crops and ornamental trees due to irrigation with stabilized pond effluent, was maintained.

Due to delays in the completion of the irrigation system, no planting was done in the summer of 1971. Early in 1972, a forage and turf consultant was hired to implement the sod crops seeding program, to inspect the turf and forage crops when they were established, and to advise in the care and harvesting of them.

All seeding of the turf and forage crops was done in 1972 between April and August. The seed was broadcast since the soils were too stony to drill.

Three forage grasses, two legumes, and one turf mixture were seeded. The grasses were reed canary, tall fescue, and creeping foxtail; the legumes were birdsfoot trefoil and ladino clover; and the turf mixture was a combination of delta and merion bluegrasses. Germination of the seed and establishment of the sod were aided by light irrigation.

Original project plans did not specify that fertilizer be used on the plant materials. It was felt that the wastewater should have sufficient nutrients to make fertilizer additions unnecessary and that added fertilizer nutrients might bias the test results or cause additional pollution loads in waters moving from the area. The initial soil tests in December, 1970, showed that the soils were mildly alkaline, very low is phosphorus, and low in potassium. No nitrogen measurements were made in these original tests. Testing of the sewage treatment ponds for a full year prior to planting and irrigation revealed that the final pond cell was exceedingly low in nitrogen forms during the growing season. Consequently, a starter fertilizer at 337 kilograms per hectare (kg/ha) of 14-7-7 was applied to all turf and fescue plots in August, 1972. No fertilizer was applied to any other plots in 1972 or to any plots thereafter through 1976.

The turf and forage crops were irrigated on a regular basis during the summers of 1973 and 1974. After these two years of irrigation, all sod crops were doing well except two. The creeping foxtail was thinly established the first year but filled in and thickened somewhat the second year. Response of the birdsfoot trefoil was so poor; after one year it was chemically killed and replaced by ladino clover. This clover was seeded in the 51 and 102 mm per week application areas in September, 1974. The trefoil plot in the 76 mm application area was too wet for seeding at that time and, therefore, was left in trefoil.

The two-year project extension (April 1, 1975 to March 31, 1977) provided time to secure added research results relative to the sod crops. Arrangement of these crops within irrigation levels as established in 1974 is shown in Figure 9. The sod research areas were irrigated from early May through mid-October with few interruptions each year of the extension period as discussed in Section 5. Inspection, maintenance, and management of the areas during this two-year period are described under the 1975 and 1976 considerations.

1975 Considerations

The forage and turf consultant made frequent inspections of all sod crops throughout the summer. In early June, his overall evaluation of the crops was that they were doing very well and that they were above average both in quality and quantity compared to non-irrigated forages growing on comparable soils in the area. The wastewater irrigated forages were ready for harvesting about the first week in June while forage crop harvesting on the general farms in the Belding area was begun about ten days later.

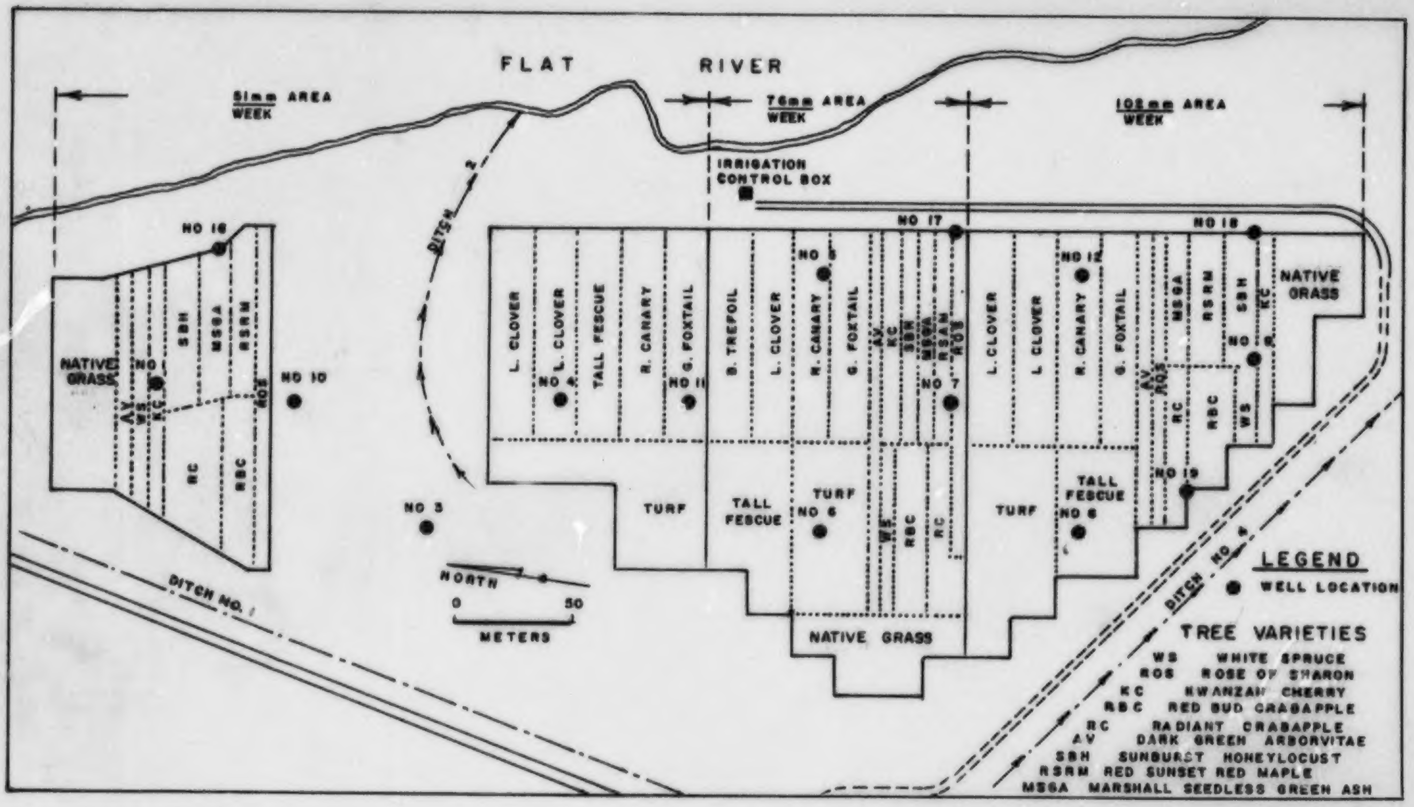
FLAT RIVER
51mm AREA / WEEK
76mm AREA / WEEK
102mm AREA / WEEK
IRRIGATION CONTROL BOX
DITCH 2
DITCH NO. 1
DITCH NO. 4
NO 3
NO 4
NO 5
NO 6
NO 7
NO 8
NO 10
NO 11
NO 12
NO 16
NO 17
NO 18
NO 19
NATIVE GRASS
L. CLOVER
TALL FESCUE
R. CANARY
G. FOXTAIL
B. TREFOIL
TURF
AV
WS
KC
SBH
MSGA
RSRM
ROS
RC
RBC
NORTH
0
50
METERS
LEGEND
WELL LOCATION
TREE VARIETIES
WS WHITE SPRUCE
ROS ROSE OF SHARON
KC KWANZAN CHERRY
RBC RED BUD CRABAPPLE
RC RADIANT CRABAPPLE
AV DARK GREEN ARBORVITAE
SBH SUNBURST HONEYLOCUST
RSRM RED SUNSET RED MAPLE
MSGA MARSHALL SEEDLESS GREEN ASH

Figure 9. Summer irrigation site showing locations of tree and sod crops.

Two harvestings of sod crops were made at the summer site. The first cutting was done June 26 and 27 and the vegetation removed about two weeks later. This work was to have been done the first week of June by a local farmer who at harvest time decided he could not schedule it. The delay in cutting permitted the tall grasses and weeds to shade low growing crops such as the ladino clover, while the forage residue left in the field for nearly two weeks caused a partial smothering of the second crop. This tall, tough and unpalatable first crop was merely trucked off the site and dumped.

The second crop was cut by a different farmer September 10 and 11, removed September 13, and several days later fed to young cattle on his farm. The cattle immediately accepted the vegetation, eating it as rapidly as it was removed from the wagon.

At the end of the 1975 growing season, a general evaluation was made of all sod crops grown on the summer research-demonstration site. These crops included the three forage grasses, the two legumes, and the turf mixture as described above. The tall fescue grass and the bluegrass turf mixture have done exceptionally well. Both thrived under heavy loadings of natural and irrigated waters, which is somewhat different than ordinarily indicated in the literature. A very thick stand of plants indicated the yield to be excellent, though no specific yield data were taken.

Reed canary grass and ladino clover both performed satisfactorily. Good performance was expected from reed canary grass as it ordinarily thrives under wet to very wet field conditions. It was a bit surprising, however, to have such a good response from ladino clover under the wet conditions. The ladino clover plots may have been even better, had the harvesting been done sufficiently early and frequently. This would have reduced weed competition and also would have permitted more direct sunlight to reach the clover. It appears that ladino clover should be planted in early summer for the best stand and yield, as that seeded in the fall of 1974 has a much thinner stand.

Neither birdsfoot trefoil nor Garrison creeping foxtail has performed satisfactorily under the wastewater irrigation at the summer site. As mentioned before, the birdsfoot trefoil did so poorly that it was replaced by ladino clover at the end of the first year. Creeping foxtail, while thinly established the first year, did thicken somewhat the second year and during 1975, it consistently deteriorated. After the initial harvest, its regrowth was very slow; and by the second cutting, it had appreciably less harvestable growth than reed canary grass as a comparison.

1976 Considerations

Two harvests were made from the summer site in 1976. The first cutting occurred on June 9 using a sicklebar mower at 10 cm height. Forages then dried on the ground until June 11 when 5170 kg were raked and baled. The cutting and raking were done by Belding personnel, while the baling was done by a local implement dealer. As part of the agreement, the implement dealer took all the baled hay. Several other persons expressed interest in securing some of the hay for horse feed.

No major quantity or quality differences were noticeable from visual inspection of the 51, 76, and 102 mm per week wastewater application plots. Strong breezes during the harvesting period and daytime temperatures of about 30 degrees Celsius provided good drying conditions. All forage bales stored well except the ladino clover. The high soil moisture content and the thick hay crop maintained too high a moisture content until baling occurred and a number of bales of clover hay mildewed.

On July 16, all harvested areas were inspected for regrowth. The weather since the first cutting had been hot and dry. All irrigated forages were growing well, whereas those not irrigated showed somewhat smaller leaf size and poorer plant quality. The summer site appeared almost ready for harvest at this time and easily should have been ready by the end of the month.

The second cutting, however, was not made until August 25. Baling occurred on September 2 (under similar weather conditions as the first harvest), and the yield was about 5350 kg from the site. It is felt the site would have produced a third cutting if fertilizer had been applied in mid-July. Fertilizer recommendation would be 45 to 55 kg/ha actual nitrogen and (optional) 80 to 90 kg/ha elemental potassium to support yields.

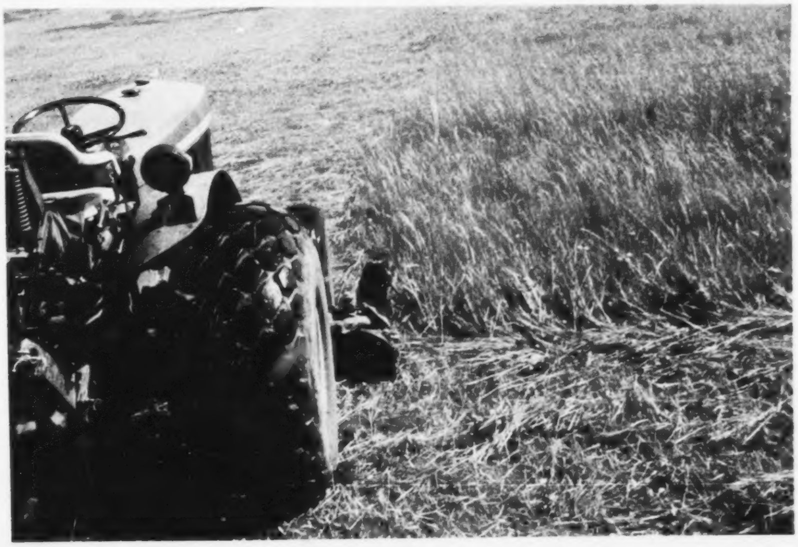

Figure 10. Tractor with cutter bar during harvesting of tall fescue grass.

Tall fescue (Figure 10) continues to prove itself as the number one forage on the Belding wastewater irrigation site. It continues to take over much of the 51 and 76 mm per week areas, showing little regard for weeds which are present. After four years, it is still thriving under heavy loadings of natural and irrigated waters, indicating wide adaptation to varying moisture conditions. From the summer of 1975 observations, the cattle fed seemed to prefer the young tall fescue over the other forages.

At the close of the fourth year, reed canary grass is a close second in the forage comparisons. Good performance was expected from the reed canary grass as it ordinarily thrives under wet to very wet field conditions. Most cattle, however, do not seem to prefer this type forage, especially at the older stages of growth. Adequate management and frequent harvestings at younger stages can overcome some of this aversion.

Ladino clover performed very satisfactorily through 1975; however, by the end of 1976, it had deteriorated appreciably both in quality and quantity. Where no grass control spray was applied, the clover is nearly gone due to grass and weed competition. Under reasonable drainage and fertilizer management, it seems this forage could serve well in a grass-legume mixture for three to four year rotation periods.

It was not possible to harvest the bluegrass turf mixture as a sod for municipal use due to an excess of small stones in the upper soil layers of the site. When left to mature as a forage grass, however, this mixture continues to grow exceptionally well. The grass mixture lacks the roughage characteristics which most ruminant animals require, but the fine textured grasses do serve well for horse feed.

Neither birdsfoot trefoil nor creeping foxtail has performed adequately under wastewater irrigation. The birdsfoot trefoil was not adequately established, perhaps due to improper or inadequate inoculation. The foxtail is managing to survive but seems limited in growth and ability to compete with annual weeds.

Sod Farm Summary

Harvesting of two forage crops in 1975 and 1976 has demonstrated that crop growth is practical on projects of this type and that harvesting can be accomplished without lengthy or untimely shutdowns of the irrigation system. Three harvests could ordinarily be made in a normal year of wastewater irrigation if supplemental fertilization is practiced. Even though tall fescue maintained itself well for four years without chemical weed control applications, annual treatment for weed control is necessary for optimum forage growth of most crops. Good surface and subsurface drainage usually enhances crop quantity and quality, especially for preferred crops such as ladino clover.

Originally, a turf grass sod was included as a practical nonfeed byproduct for town beautification and erosion control. Under conditions at the Belding site, bluegrass seed has germinated and grown comparable to a commercial sod farm. If the turf plots had received normal sod producing fertilization rates, Belding's sod would compare in quality to commercial sod. This statement is made, recognizing only one application of fertilizer has been made to the plots in the four years. Excessive stoniness of the site made it uneconomical to harvest the turf for municipal use.

The tall fescue and reed canary crops are thriving after four years of wastewater irrigation and are the types of grasses which may be used for continuous cover without crop rotation. Ladino clover could be used in a grass-legume mixture under a rotation system, as three years of hay followed by three years of corn. Under conditions as found at Belding, it seems unwise to use either birdsfoot trefoil or creeping foxtail.

To obtain an indication of the feed value of the forages grown under wastewater irrigation, a number of tissue tests were run on fescue and canary grass samples from the 102 mm per week area (Table 13). Both grass cuttings portray good feeding value with nitrogen, crude protein, and total digestible nutrients of the reed canary grass being slightly higher in each sample than those of the tall fescue. The September data are from growth under irrigation and essentially no natural precipitation. The major differences between the September and July data, however, seem to be that the boron doubled while the potash decreased appreciably. The low potash levels indicate deficiency and that this nutrient could be limiting crop yield. After four years of irrigation, there appears to be no problem with the quality of forage for use as animal feed.

Each year since 1972, soils in the irrigation areas have been tested to determine nutrient level changes (Table 14). Analysis for the years 1972 through 1975 were made by the same laboratory while the data for 1976 were from a different laboratory. There seems to be no good explanation for the consistently high values of the four analyzed nutrients in 1975 followed by consistently low levels of all in 1976.

TREE NURSERY

Original plans did not specify the types of trees to be planted other than that they would be ornamental and usable for city beautification. Meetings with a tree nursery specialist yielded a plan for comparing nine ornamental tree types having known resistence to wet soil conditions. These nine were: White Spruce, Rose-of-Sharon, Kwanzan Cherry, Redbud Crabapple, Radiant Crabapple, Dark Green Arborvitae, Sunburst Honeylocust, Red Sunset Red Maple, and Marshall Seedless Green Ash. Their arrangement in the research plots and their location relative to the other crops are shown in Figure 9.

All trees were planted during May and June of 1972. As indicated by the 1970 soil tests, no fertilizer was required. The tree consultant gave advice and assistance during the planting operation and continues to present recommendations on trimming, pruning, shaping, spraying, and other management activities as required for good nursery practice.

TABLE 13. TISSUE ANALYSIS SHOWING QUALITY OF FESCUE AND CANARY GRASSES FOR BOTH CUTTINGS MADE IN 1976

	Tall Fescue 9/22/76	Reed Canary 9/22/76	Tall Fescue 7/13/76	Reed Canary 7/13/76
Moisture %	0.00	0.00	0.00	0.00
Crude Protein %	9.25	11.12	9.93	10.43
Digestible Protein %	4.90	6.45	5.46	5.63
Crude Fat %	2.25	2.40	2.45	2.40
Crude Fiber %	32.40	28.90	30.50	30.90
NFE % (CAR-HYD.)	47.97	48.75	49.26	50.91
Digestible CAR-HYD. %	49.93	50.65	52.31	53.55
Ash %	8.13	8.82	7.85	5.35
Total Digestible Nutrients %	54.83	57.11	57.78	59.18
Nitrogen %	1.48	1.78	1.59	1.67
Phosphorous %	.31	.34	.29	.27
Potassium %	1.46	1.79	1.96	2.18
Magnesium %	.24	.28	.16	.20
Calcium %	.400	.420	.220	.300
Sodium %	.180	.160	.100	.010
Iron PPM	137.0	102.0	182.0	97.0
Aluminum PPM	82.0	49.0	115.0	35.0
Manganse PPM	97.0	66.0	59.0	28.0
Boron PPM	24.0	26.0	12.0	9.0
Copper PPM	8.0	9.0	6.0	8.0
Zinc PPM	20.0	26.0	16.0	26.0

TABLE 14. SOIL SAMPLE HISTORY OF SUMMER WASTEWATER IRRIGATION SITE

		Phosphorus*	Potassium*	Calcium*	Magnesium*	pH
2" Reed	1976	13	32	1300	175	7.2
	1975	54	74	3860	474	7.0
	1974	15	62	1860	195	7.8
	1973	17	38	2040	176	7.5
	1972	13	44	2300	170	7.5
2" Turf	1976	10	34	1300	160	7.3
	1975	40	92	4660	626	6.8
	1974	16	50	1470	160	7.7
	1973	21	47	1880	197	7.2
	1972	18	40	2000	200	7.5
3" Reed	1976	5	29	1850	335	7.1
	1975	36	98	6240	852	6.6
	1974	15	54	2130	305	7.4
	1973	14	49	3000	415	7.4
	1972	9	56	3000	353	7.0
3" Turf	1976	NA	NA	NA	NA	NA
	1975	82	98	3080	496	6.6
	1974	26	66	2040	251	7.4
	1973	26	52	2600	316	7.4
	1972	24	69	2300	240	7.4
4" Reed	1976	52	47	1150	195	7.1
	1975	128	90	2420	404	6.8
	1974	45	69	1570	223	7.6
	1973	63	78	1740	251	7.6
	1972	21	62	2700	190	6.8
4" Turf	1976	30	37	1150	200	7.0
	1975	98	132	2980	396	6.3
	1974	30	89	1640	204	7.6
	1973	40	61	2040	243	7.7
	1972	19	53	2100	190	7.4

*All data except pH are in mg/l.

At the end of the 1973 irrigation season, most of the trees were progressing well and were in healthy growing condition with an overall survival rate since planting of about 90 percent. The green ash and red maple exhibited high growth rates in response to irrigation. Problems due to excess wetness, however, were apparent in some locations and corrective drainage was recommended.

Appropriate drainage and overall good management, however, were not carried out in all the research areas which gave an excellent demonstration of the effect when less than diligent management is maintained for effluent irrigation facilities. Following are listed certain 1974, 1975 and 1976 results in each of the 102, 76 and 51 mm per week application areas. The available tabulated tree growth and tree mortality data are listed in Figures 15 and 16, respectively.

1974 Considerations

All species in the 102 mm per week area, with the exception of Red Sunset Red Maple, added more new growth this year than in 1973. The reason for such good growth may be attributed to the sufficient cultural attributes that were present--weed competition was certainly less and drainage was appreciably better than in the other areas. As a result, mortality was less in this area.

Trees in the 76 mm per week area grew less than in 1973. Perhaps the most significant reason for this was the presence of a large wet section that covered over half of the area. Many tree species that were barely able to survive in the wet area last year did not make it this year. As a result, all the Redbud Crabapple, except three or four, died. Approximately 50 Radiant Crabapple and 60 Sunburst Honeylocust also died due to lack of adequate drainage.

Lack of cultural practices caused severe damage in the 51 mm per week area. Weeds, rocks, and a high water table were evidence in this area that the trees could not compete satisfactorily. For example, 65 Redbud Crabapple were killed by fireblight, only 18 Kwanzan Cherry survived, and all the Sunburst Honeylocust died.

1975 Considerations

An evaluation was made of the tree nursery early in May, 1975, to determine the most efficient procedures for the two-year research-demonstration extension. The 102 mm per week wastewater application area was doing very well due to reasonable natural soil drainage and consistent tree maintenance. The trees exhibited good growth with no major adverse effects except a relatively high incidence of fungal disease in the crabapple block resulting from high humidity and a possible indication of nutrient deficiency stress from competition of a vigorous sod cover.

The 51 mm per week area showed a high degree of stress as it had from the beginning. Most of this stress was due to poor natural drainage of the area. Also, poor drainage prevented good maintenance; and poor maintenance permitted disease, rodent and weed problems. The 76 mm per week area was somewhere between the 51 and 102 mm areas in performance. Poor natural drainage resulted in mortality for most of the trees in certain sections of the 76 mm area, whereas in other sections the trees were doing reasonably well.

From this evaluation, it was agreed that the 102 mm per week areas should be maintained at the highest possible level, the 51 mm area should merely be irrigated and left to survive as best it could, and maintenance of the 76 mm area should be somewhere between the 51 and 102 mm areas as time permitted. It was felt this maintenance scheme would give a good demonstration of the effects of poor to good management practices during 1975 and 1976 seasons.

Maintenance operations throughout the summer of 1975 were performed on a ten-day to two-week interval schedule. The tree consultant presented recommendations on, and assisted with, all management activities as required for good nursery practice. In addition, the 102 mm per week area was mowed during the summer; and on several occasions, the larger weeds were removed from around the trees.

At the end of the 1975 growing season, a general evaluation was made of the performance and condition of the trees under each irrigation level. Terminal and lateral branches of the trees in the 102 mm per week area exhibited less growth in 1975 than in 1974 (Table 15), but the trunk diameter growth increased. Tree crowns in this area looked much improved from a year ago, and it is the crown appearance that is important when evaluating the quality of a block of trees. Disease and insects, such as aphids on green ash, red spider mites on honeylocusts, and fireblight on crabapples were substantially less in the 102 mm area in 1975 than in 1974. This was primarily due to frequent applications of insecticides and fungicides in 1975. Mortality in the 102 mm area did not increase since the 1974 count.

Crown growth in the 76 mm per week area also was less in 1975 than in 1974 (Table 15). In sharp contrast to the 102 mm area, however, the crown form of the red maples, honeylocusts, and green ash was quite poor. The high water table and poor drainage that exists on the 76 mm area was probably responsible for the slower growth. Disease and insect incidence in the 76 mm area was quite low in 1975, due in part to the spraying that was conducted. Since 1974, 11 additional red maples died and the quality of the surviving trees is quite poor, both in vigor and in form.

Proper management of the 51 mm per week area was considered economically prohibitive due to a high water table, poor surface drainage, and excessive numbers of large stones. Also, since many of the trees had died over the past two years, clearing of the land and performing adequate tree maintenance of the existing trees was not justifiable. Thus, it was recommended that existing trees worth salvaging be transplanted in municipal

TABLE 15. TERMINAL AND CALIPER TREE GROWTH - 1974, 1975, AND 1976 (cm)

Block	Criterion	RC	MSGA	RSRM	RBC	SBHL	KC
1974							
76mm	terminal	7.62	25.40	24.13	dead*	21.59	dead
76mm	caliper	1.91	2.87	2.54	dead	1.68	dead
102mm	terminal	18.80	41.40	27.43	29.97	32.51	16.51
102mm	caliper	2.54	3.18	2.54	3.51	1.91	3.18
1975							
76mm	terminal	dead	21.97	10.39	dead	11.53	dead
76mm	caliper	dead	3.25	2.54	dead	2.54	dead
102mm	terminal	22.86	39.85	17.04	22.61	26.24	11.43
102mm	caliper	3.30	4.14	2.79	3.89	2.03	3.63
1976							
76mm	terminal	dead	15.14	dead	dead	dead	dead
76mm	caliper	dead	3.56	dead	dead	dead	dead
102mm	terminal	30.73	34.54	8.64	24.89	28.96	14.22
102mm	caliper	3.91	4.83	2.79	4.32	3.05	3.81

KEY:

RC	Radiant Crabapple
MSGA	Marshall Seedless Green Ash
RSRM	Red Sunset Red Maple
RBC	Redbud Crabapple
SBHL	Sunburst Honeylocust
KC	Kwanzan Cherry

*"Dead" implies that all the trees had died or were of no practical value for transplanting.

parks and along city streets and that the remainder of the trees be left in the field.

1976 Considerations

Examination of tree performance in the 102 mm per week area (Table 15) illustrates that certain species did exceedingly well, especially the green ash (Figure 11) and the Radiant and Redbud Crabapples. The green ash and the Radiant Crabapple exhibited growth comparable to commercially grown nursery stock. The excellent growth rate of green ash was expected since there was an abundance of both irrigation and ground water in the eastern section of this area.

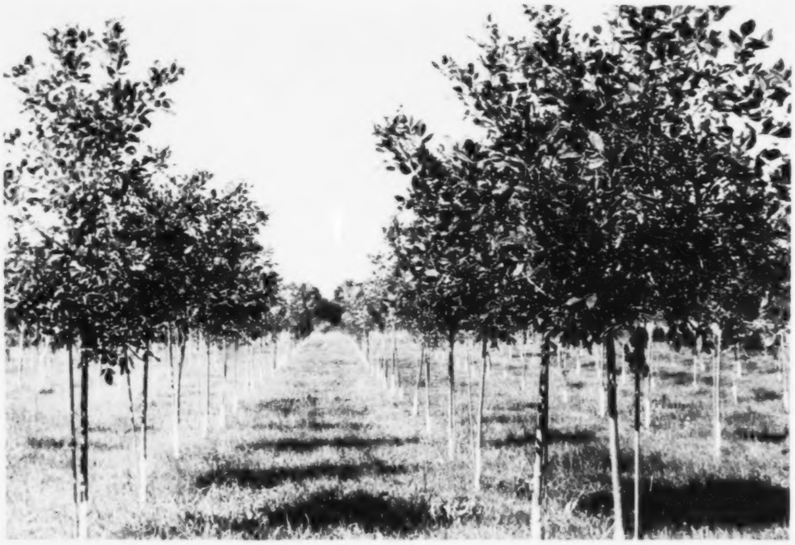

Figure 11. Marshall seedless green ash in 102 mm per week application area with one year of growth remaining before transplanting. (Note lower trunks fitted with white plastic guards to prevent rodent damage.)

Other species in the eastern section of the 102 mm area, namely red maple, Sunburst Honeylocust, and Kwanzan Cherry did not perform well under these wet conditions. This year, there was a 19.6 percent increase in mortality in the Red Sunset Red Maple, giving a mortality of 47.1 percent since planting in 1972 (Table 16). Of the red maples presently alive, only 20 percent were suitable for transplanting. The remainder were in a very weak condition which many have exhibited since planting.

Although the Sunburst Honeylocust were small at this time, they have shown signs of improvement in form as a result of intensive staking, trim-

TABLE 16. TREE MORTALITY - 1975 AND 1976

Block	Variety	Total Planted	No. Dead	Mortality,%	Change From 1975,%
		1975			
102mm	RC	101	2	1.9	
102mm	RBC	101	34	33.6	
102mm	MSGA	87	8	9.1	
102mm	RSRM	87	24	27.5	
102mm	SBHL	86	14	16.2	
102mm	KC	40	31	77.5	
76mm	MSGA	90	5	5.5	
76mm	RSRM	85	26	30.5	
76mm	SBHL	85	58	68.2	
		1976			
102mm	RC	101	2	1.9	0.0
102mm	RBC	101	34	33.6	0.0
102mm	MSGA	87	8	9.1	0.0
102mm	RSRM	87	41	47.1	19.6
102mm	SBHL	86	19	22.0	5.8
102mm	KC	40	31	77.5	0.0
76mm	MSGA	90	5	5.5	0.0
76mm	RSRM	85	73	85.0	54.5
76mm	SBHL	85	74	89.0	18.8

KEY:		
	RC	Radiant Crabapple
	MSGA	Marshall Seedless Ash
	RSRM	Red Sunset Red Maple
	RBC	Redbud Crabapple
	SBHL	Sunburst Honeylocust
	KC	Kwanzan Cherry

Note: In the 76mm block prior to the 1975 mortality check, all the Kwanzan Cherry and the Radiant and Redbud Crabapples had died or were in too weak a condition for transplanting.

ming and red spider mite control. Since this species grows moderately well in poorly drained sites, it has responded more favorably to cultural techniques than the red maple and the cherry.

In addition to the deciduous trees in the 102 mm per week block, arborvitae, rose-of-sharon, and white spruce were planted. In 1976, all 43 of the arborvitae planted were continuing to grow and averaged nearly 2 m in height, 21 rose-of-sharon of the 42 planted were still growing and averaging 1 m in height, and only seven white spruce of the 34 planted had survived and these averaged about 0.5 m in height. The poor performance of the white spruce was attributed primarily to lack of weed control.

Presently (Spring, 1977), in the 102 mm per week area, the number of trees suitable for transplanting throughout the City of Belding are listed below. Also, there should be more Sunburst Honeylocust suitable for transplanting when they attain a larger size.

20 Rose-of-Sharon
99 Radiant Crabapple
45 Redbud Crabapple
78 Marshall Seedless Green Ash
15 Sunburst Honeylocust
10 Red Sunset Red Maple
43 Dark Green Arborvitae

The 76 mm per week block of trees has been deteriorating annually since planting in 1972. Prior to 1976, all of the Kwanzan Cherry and the Radiant and Redbud Crabapples had died or were in too weak a condition to be considered for transplanting. This mortality is attributed primarily to the lack of drainage; however, lack of proper management was a contributing factor.

Tree performance data for 1976 (Table 15) indicate that the red maple and the honeylocust remaining from 1975 had either died or were of too poor quality to try to maintain. The mortality data (Table 16) indicate that over 50 percent of the red maple in this block were lost during the last year. The high loss of red maple in both the 76 and 102 mm per week areas plus observations in very early 1976 indicate much of this loss could have been due to winter killing, which indirectly was due to a very high water table.

The only trees suitable for transplanting from the 76 mm per week block were 55 Marshall Seedless Green Ash and 23 of the original 45 arborvitae. The remaining trees were lost due to poor drainage and/or inadequate management.

Irrigation was the only function performed in the 51 mm per week area during 1976 where all the trees had either died or were of such form that few were of ornamental value to the town.

At the end of the 1976 growth season, the tree consultant emphasized the need of removing the transplantable trees as soon as possible. This was primarily for two reasons: (1) the caliper of many trees was becoming quite large and would soon be too large for economical transplanting; and (2) some of the weaker trees, especially among the Red Sunset Red Maple and the Sunburst Honeylocust, would decline even more in the future if they were not soon transplanted to more favorable sites.

Tree Nursery Summary

A city can grow ornamental trees for municipal beautification with the use of its wastewater and nutrients. This is attested to by the fact that over 300 ornamental trees in the 102 mm per week irrigated area were grown to a transplanting stage in the City of Belding. There were also nearly 100 trees in the 76 mm per week area ready for transplanting in 1976, while in the 51 mm area very few desirable trees remained.

Two causes are attributed to the disparity of transplantable trees among the three irrigation levels. The primary reason for loss of trees in the 76 and 51 mm areas was excessive wetness and high water table due to natural plus irrigated waters. The secondary cause of tree loss in these two areas was poor overall maintenance.

The tree consultant on several occasions outlined a program of management which could have saved over half of the trees that were lost. These management recommendations included: a spray program for control of the many types of insects, disease and fungi; a drainage program including both surface and subsurface drains; a fertilizing program to provide nutrients not supplied by the wastewater; a tree care program of pruning, staking, etc.; and a weed control program of mowing and spraying to reduce competition for available nutrients.

This project demonstrated the possibility of a municipality growing its own ornamental trees. It also demonstrated the level of management required to produce transplantable quality trees. The type of land available and the extent and quality of management required to produce the number of trees desired, however, will need to be evaluated on a cost-effective basis by each municipality before implementing this type of project.

SECTION 7

REMOVAL OF NUTRIENTS

Removal of nutrients from municipal effluent before these nutrients enter a body of water and degrade its quality is of national concern, and land application is one method presently being considered for this removal. The degree of nutrient removal is determined by comparing the quality of water moving from an irrigation area with the quality irrigated.

Wastewater renovation data from only the summer site are included in this section of the report. Both surface and subsurface quality of water leaving the irrigation site are discussed. The surface quality is determined from water leaving the site in open drainage ditches and also as surface runoff from the 76 and 102 mm per week application areas. Subsurface quality is of samples secured from monitoring wells located in the summer site.

DITCH WATER QUALITY

Water quality samples were secured from four ditches. These include: ditch 1 west of the summer irrigation site; ditch 2 through the swale in the 55 mm per week application area; ditch 3 east of pond cells 2 and 3; and ditch 4 north of cells 4 and 5 and south of the summer irrigation site.

Ditch water quality data for the summers of 1972 and 1973 (Table 17) help define water movement patterns in the area surrounding the summer site. The 1972 data were secured before irrigation was begun; thus, they indicated background or baseline conditions in these ditches. The 1973 data are for the first full year of irrigation at the summer site.

Comparison of the 1975 and 1976 data (Table 18) from ditch 1 with those of ditch 1 in 1972 shows no change of quality. The most recent two year's results are typical of all data secured from ditch 1 since irrigation began in May, 1973,and indicate no untreated irrigation effluent is moving into this ditch. A slight increase in phosphorus content in ditch 2 over the years, however, indicates some runoff or other untreated effluent is entering this channel.

When comparing the data from ditches 1 and 2 with those of ditches 3 and 4 for all years, it is apparent that appreciable amounts of pond water seep from the cells into the adjacent ditches. Ditches 3 and 4 usually have chloride in excess of 100 mg/l, phosphorus frequently in excess of 1 mg/l, and ammonia nitrogen on occasion in excess of 7 mg/l; however, the levels of concentrations have not significantly changed over the four years of record.

TABLE 17. DITCH WATER QUALITY FOR SUMMERS OF 1972 AND 1973
(mg/l except pH)

Parameter	Summer 1972 Ditch No.				Summer 1973 Ditch No.			
	1	2	3	4	1	2	3	4
pH	6.9–8.5	7.4–8.1	7.1–7.7	7.1–7.6	7.1–7.7	7.4–7.9	7.1–7.6	7.2–7.8
Cl	6–8	2–5	124–166	123–160	6–8	3–10	119–140	107–126
NH_3-N	0.1–0.2	0.1–0.4	4.0–7.6	5.5–7.3	0.1–0.2	0.1–0.3	1.8–5.3	3.4–3.6
NO_3-N	1.1–1.8	0.4–0.8	2.4–7.6	3.4–7.3	0.8–2.0	0.3–0.8	0.2–0.3	0.0–0.2
TKN					0.2–1.7	0.2–1.3	2.0–6.1	2.2–13
Ortho P	0.0–.01	0.0–.01	.16–2.1	0.3–1.8	0.0–.02	0.0–.02	.05–.98	.66–1.7
Total P	.01–.02	.01–.03	0.3–2.2	0.4–2.4	.02–.03	.01–.03	.16–3.7	.68–1.8

TABLE 18. DITCH WATER QUALITY FOR SUMMERS OF 1975 AND 1976

(mg/1 except pH)

Parameter	Summer 1975 Ditch No.				Summer 1976 Ditch No.			
	1	2	3	4	1	2	3	4
pH	7.5-8.1	7.7-8.1	7.4-8.0	7.5-8.1	7.3-8.1	7.7-8.3	7.5-8.0	7.4-7.9
Cl	7-16	4-7	70-110	75-175	7-12	4-8	85-135	65-90
NH_3-N	.01-.08	.05-.48	1.0-3.9	0.6-5.7	0.0-0.1	0.1-0.2	0.3-5.0	1.9-4.0
No_3N	1.0-1.3	0.3-.7	0.1-0.8	0.2-0.5	1.1-1.4	0.7-0.9	0.2-0.5	0.1-0.5
TKN	0.4-1.1	0.5-1.7	3.1-5.8	3.6-5.8	0.3-1.7	0.6-1.2	1.4-5.2	2.4-5.0
Ortho P	.01-.02	.01-.04	0.9-1.9	.03-0.8	.01-.04	.01-.06	0.1-0.6	1.3-2.1
Total P	.01-.03	.02-.07	1.0-2.3	0.4-3.4	.02-.05	.02-0.1	0.7-2.1	1.5-2.6

SURFACE RUNOFF QUALITY

Some surface runoff from the summer site had been noted during the 1973 and 1974 irrigation seasons. What to do with this surface flow was discussed on May 8, 1975, when personnel of the Environmental Protection Agency, Michigan Department of Natural Resources, Belding, and Williams & Works met to consider the proposed project extension. It was agreed that three monitoring locations should be established - two on the 102 mm per week and one on the 76 mm per week area where surface water naturally drains from these plots. It also was agreed that samples from the two locations on the 102 mm area should be mixed and the composite analyzed as a single unit; that the samples should be taken with the same frequency as the ground water monitoring wells in the summer irrigation site; and that the parameters measured should include the pH, the three nitrogen forms, and the two phosphorus forms.

During both the 1975 and 1976 irrigation seasons, runoff water from the 76 and 102 mm per week areas was sampled at intervals from June through October. No runoff from these areas occurred before June; also, no runoff was evident during many irrigation periods throughout the summer. Better established crops these years with higher amounts of transpiration probably aided in reducing the runoff. Infiltration of the soils, disturbed during construction, also probably improved over the years as the grass roots help loosen compacted soils.

No runoff from the 76 mm area was noted while the 102 mm area was being irrigated. This indicates relatively little surface water moving from the 102 mm to the 76 mm area. Some of this reduction from previous years was due to drier soil conditions while some was also probably due to the asbestos barrier installed between the two areas for this purpose.

Four samples of runoff were secured from each of the 76 and 102 mm per week application areas in 1975 while six were secured from the 76 mm area and seven from the 102 mm area in 1976. Ranges of constituents in these samples and in the samples of effluent applied are listed in Table 19.

The pH of the runoff each year, compared with the water applied, was lower but not by a significant amount. Ortho
ranged up to 50 percent lower in the runoff than in the water applied. It should be noted that the total phosphorus levels of the runoff usually were reduced more than 80 percent from those of the influent to the pond system, which ranged from about 2 to 12 mg/l. The reduction of phosphorus probably was due to the uptake by the crops or adsorption by the surface soil similar to phosphorus reduction mechanisms in overland flow treatment systems.

Respective nitrogen values of the runoff and the water applied were essentially the same for both years, or possibly the runoff values were slightly higher. When comparing all of these values with the nitrogen levels of Table 17 for ditch 1, one notes there are no real differences among any of them. This indicates the nitrogen levels in the runoff represent background conditions and thus give no measure of renovation of the runoff.

TABLE 19. RANGES OF CONSTITUENTS IN RUNOFF FROM THE 76 AND 102 MM AREAS COMPARED WITH CONSTITUENT LEVELS IN THE WATER APPLIED, JUNE THROUGH OCTOBER 1975 AND JUNE THROUGH OCTOBER 1976

(mg/l except pH)

1975*

Constituent	Runoff		Water Applied
	76 mm area	102 mm area	
pH	7.6-8.3	7.8-8.4	7.6-9.1
NH_3-N	0.1-0.5	0.1-0.3	0.1-0.2
NO_3-N	0.1-0.3	0.1-0.3	0.1-0.2
TKN	1.2-2.6	1.4-2.2	1.4-2.3
Ortho P	0.2-1.6	0.5-1.6	0.6-3.0
Total P	0.8-1.6	0.5-1.7	0.6-2.7

*Four samples of runoff were secured from each of the 76 and the 102 mm areas.

1976**

pH	7.9-8.6	7.8-8.0	7.8-8.7
NH_3-N	0.1-0.5	0.1-0.6	0.1-0.4
NO_3-N	0.1-0.3	0.2-0.3	0.1-0.3
TKN	0.1-4.2	1.9-3.9	1.2-4.6
Ortho P	0.5-2.1	0.8-3.0	0.9-5.2
Total P	0.6-2.6	0.9-3.0	1.2-5.6
Cl	75-155	135-175	120-135

**Six samples of runoff were secured from the 76 mm area and seven samples from the 102 mm area.

Chloride levels of the runoff were not secured during 1975 but are listed in 1976 for both the runoff and the water applied. Comparative levels of this constituent indicate essentially no dilution of the irrigated water before runoff. This implies no artesian flow, but merely surface runoff due to insufficient lateral transmissibility. Higher chloride levels for runoff than for applied water in the 102 mm per week area indicate crop transpiration of pure water out of the chloride-water mix. The runoff problem could be alleviated by a reduced level of application or by providing subsurface drains.

WELL WATER QUALITY

Ground water quality data at the summer irrigation site were secured from 15 wells with elevations and locations as described in Section 5. Eleven of these wells were in operation since 1970 and four of them were added late in 1974.

Since the primary concern of this research was crop nutrients, phosphorus and nitrogen were the only nutrient constituents monitored throughout the project. In addition, chloride concentrations were determined for use in identifying the irrigated component of groundwater.

Wells 9, 12E and 12W lie in the path of ground water draining from most of the 102 mm and some of the 76 mm per week application areas and, therefore, were expected to give the quickest response. These wells showed significant increases in chloride concentrations (Table 20) due to the 1973 irrigation, with well 9 showing a major response as early as July 9. The rise of chloride to values exceeding 190 mg/l is a little surprising since chloride values measured in the ponds rarely have exceeded 160 mg/l. The wastewater apparently reached these wells often as undiluted effluent, and occasionally in slightly concentrated condition due to evaporation or crop uptake of water.

Irrigation during the summer of 1974 produced chloride responses in wells 5, 6, 7 and 8 in addition to the three wells which responded the previous year. The chloride concentrations in these seven wells fluctuated due to the dilution effects of rainfall and to the concentration effects of plant use and evaporation.

During 1975 and 1976, wells 5, 6, 7, 8, 9, 12E and 12W continued to produce strong chloride responses, while wells 3, 4, 10W and 13 maintained their background concentrations of this constituent. Well 13 is a check well located west of ditch 1. Recently installed wells 16, 17, 18 and 19 all showed chloride responses, indicating irrigation water moving past their locations. Concentrations in wells 16 and 19 indicate dilution with natural waters, whereas wells 17 and 18 from June through December indicate nearly all waters passing their locations are essentially undiluted effluent.

The phosphorus contents of wells 3, 4, 10W and 13 ranged from 0.01 to 0.04 mg/l (Table 21). These concentrations can be considered background levels since it was established by chloride concentrations that these wells receive essentially no irrigated component of wastewater. Thus, nearly complete removal of phosphorus from the wastewater was affected by the plants and soils

TABLE 20. CHLORIDE IN GROUND WATER
(mg/l)

	Well number																		
	Summer irrigation site																		
Date	1	3	4	5	6	7	8	9	10E	10W	11E	11W	12E	12W	13	16	17	18	19
12/24/70	7.0	11.0	3.0	4.0	4.0	3.0	4.0		3.0	2.0	0.0		2.0	1.0	7.0				
1/04/71																			
3/06/71	5.0	4.0	0.0	0.0	1.0	2.0	1.0	1.	1.0	0.0	0.0	0.	3.0	0.0	4.0				
8/06/71																			
9/02/71																			
2/26/72		2.0	0.0	1.5	2.5	4.0	4.0	0.	21.0				3.5	5.0	5.5				
5/02/72		6.0	5.0	2.0	3.0	5.0	4.0			16.0	0.0	0.	5.0	9.0					
6/19/72	2.0	6.0	3.0	1.0	1.5	3.0	4.0	39.	12.0	15.0	0.0	0.	5.0	26.0	7.0				
7/25/72	3.0	5.5		8.0	4.5	5.0	5.0	36.	7.8	7.8	0.0	1.	7.4	7.5	6.5				
8/14/72	3.0	6.0		11.0	2.0	4.5	5.0	35.	7.8	7.8	0.0	0.	7.6	7.6	6.0				
8/28/72	2.0	5.0		15.0	1.0	3.0	4.0	29.	7.7	7.9	0.0	0.	7.5	7.7	5.0				
9/12/72	1.0	4.0		15.0	1.0	4.0	4.0	33.	11.5	13.5	0.0	0.	3.0	4.0	4.0				
9/27/72	0.5	4.0		18.0	1.0	4.0	5.0	40.	11.5	14.0	0.0	0.	4.0	4.0	5.0				
10/10/72	2.0	4.0		24.0	2.5	5.0	5.0	45.	13.0	15.0	0.0	0.	6.0	5.0	6.5				
10/26/72	3.0	4.5		24.0	1.0	5.0	5.0	54.	0.3	0.2	0.0	0.	2.5	0.7	6.0				
2/13/73	3.0	5.0		5.0	4.0	4.5	5.5	40.	13.5		0.0		5.0	7.0	7.0				
3/08/73																			
3/26/73																			
3/29/73		6.5		4.5	4.5	6.5	6.5	31.		15.0		0.	8.5	6.5	7.5				
4/02/73																			
4/09/73																			
4/12/73	4.0	6.0		4.0	5.0	6.0		29.		17.0	0.0	0.	13.0	18.0	7.5				
4/16/73																			
4/26/73		5.5		3.5	5.0	6.0	5.5	27.		17.0	0.0	0.	14.0	10.5	7.0				
5/14/73		5.5	1.5	3.0	5.0	6.0	3.0	18.		17.0	0.0	0.	23.0	24.5	7.0				
5/29/73	12.0	5.5	0.5	3.0	5.0	7.0	5.5	36.		16.5	0.0	0.	25.0	5.5	7.0				
6/11/73	17.5	5.0	2.0	3.0	5.0	6.5	6.0	42.		1.8	0.5	0.	3.5	10.0	6.0				
6/25/73	20.0	6.0	3.0	4.0	4.0	6.5	6.0	56.		16.5	0.0	0.	6.0	8.0	6.0				
7/09/73		6.5	2.0	5.0	4.0	6.5	6.0	116.		17.0	0.0	0.	35.0	6.0	6.0				
7/23/73		7.0	3.0	6.0	4.5	8.0	7.0	140.		17.5	0.0	0.	56.0	2.5	7.0				
8/06/73	17.0	5.0	3.0	7.0	3.0	7.0	6.0	101.	15.0	16.0	0.0	0.	69.0	0.0	5.0				
8/20/73	12.0	7.0	5.0	9.5	4.0	8.5	7.0	160.	15.0	17.0	0.0	0.	101.0	3.5	5.5				
9/20/73	11.0	5.5	4.5	15.0	2.0	7.0	6.5	182.	14.0	16.0	0.0	0.	136.0	104.0	6.5				
10/15/73	13.0	5.0	3.0	23.0	1.5	8.0	6.5	182.	16.0	17.0	0.0	0.	174.0	107.0	6.0				
1/04/74																			
1/09/74			2.0			9.0		154.					177.0	191.0	9.0				
2/12/74							8.0												
3/07/74		5.0	0.0	70.0	14.0	17.0		84.0		16.0	0.0	0.	16.5	155.0	7.0				
7/09/74		9.0	2.0	18.0	58.0	20.0	29.0	82.0	17.0	17.0	0.0	1.	110.0	180.0	7.0				
7/30/74		6.0	1.0	77.0	103.0	19.0	31.0	158.0	15.0	15.0	0.0	0.	20.0	165.0	7.0				
8/19/74		5.0	1.0	79.0	120.0	19.0	30.0	175.0	16.0	16.0	0.0	0.	50.0	15.0	6.0				
9/09/74		6.0	1.0	90.0	125.0	21.0		135.0		16.0	0.0	0.	140.0	4.0	6.0				
10/07/74		6.0	2.0	90.0	130.0	18.0		175.0		16.0	0.0	0.	190.0	205.0	6.0				
10/21/74		6.0	1.0	95.0	135.0	19.0		170.0		15.0	0.0	0.	165.0	180.0	7.0				
11/04/74		7.0	1.0	90.0	135.0	18.0	19.0	165.0		16.0	0.0	0.	175.0	180.0	6.0				
11/25/74		5.0	0.0	100.0	110.0	18.0	17.0	130.0		14.0	0.0	0.	170.0	160.0	5.0				
12/16/74		7.0	1.0	115.0	70.0	21.0	23.0	115.0		16.0	0.0	0.	175.0	100.0	6.0				
1/07/75				115.0	75.0	24.0	29.0	155.0					80.0	60.0	7.0				
1/29/75			2.0	120.0	80.0	35.0	28.0	150.0			0.0	0.	105.0	120.0	9.0				
2/19/75				110	75	25	20	135					120	145					
3/05/75		6	1	100	90	28	24	95					115	150	8				
3/25/75				95			30	70					120	160	10		125	170	95
4/07/75		5	0	85	125	30	27	50	14				110	160	7	8	90	160	85
4/29/75		5	1	80	130	37	26	60					180	165	7	6	11	155	90
5/19/75		6	3	75	135	40	27	40		16	0	0	195	180	6	8	11	140	100
6/17/75		7	1	85	115	39	57	75		17	0	0	55	175	5	14	150	110	90
7/07/75		7	1	95	115	28	45	125		17	0	0	90	130	6	7	155	115	95
7/21/75		5	1	90	105	34	30	140		16			120	120	5	18	145	120	75
8/11/75		6	0	105	105	31	45	190		17	0	0	135	70	6	58	200	95	80
9/02/75		6	1	110	95	24	35	175		16			160	9	5	75	195	120	80
9/22/75		6	1	100	120	31	40	160		16	0	0	175	50	6	50	175	145	80
10/07/75		6	1	105	110	165	35	130		17			170	130	5	40	165	150	75
10/27/75		7	0	100	85	30	28	130		17			170	85	5	39	120	155	85
11/24/75		7	1	100	75	28	23	135		17			95	65	8	28	125	155	100
12/16/75		7	0	105	55	35	35	130					70	40	6	24	130	160	90
1/14/76			0	115	50		32	140					50	35	6		145	155	85
2/10/76		6	0	105	50	33	30	130		17	0	0	130	85	6	12	135	150	65
3/9/76		6	0	95		37	46	95					85	130	6		35	140	75
3/30/76		5	0	80	33	36	35	80		16	0	0	120	135	6	6	5	140	80
5/11/76		7	0	80	50	37	46	12		17	0	0	145	175	5	6	23	110	70
6/02/76				75	37	39	79	40					130	180		6	117	95	85
6/22/76		7	0	75	56	37	75	55		17			15	180	6	5	105	75	75
7/11/76		8	1	80	40	35	70	125		16	0	0	41	155	8	9	150	80	85
8/3/76		6	0	90	80	35	65	135		16			90	100	6	17	190	85	80
9/8/76		7	1	95	90	35	45	150		16	0		120	40	5	6	175	75	50
9/29/76		7	1	85	90	25	30	170		15	0		155	18	5	44	135	115	60
10/20/76		35	0	100	80	31	52	160		16	0		160	160	7	101	205	105	75
11/8/76				105	70	30	38	160					160	70		76	195	115	89

TABLE 21. TOTAL PHOSPHORUS IN GROUND WATER
(mg/l)

Date	Well number																		
	Summer irrigation site																		
	1	3	4	5	6	7	8	9	10E	10W	11E	11W	12E	12W	13	16	17	18	19
12/24/70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
1/07/71																			
3/06/71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
8/06/71	0.95	0.04	0.01	0.025	0.09	0.01	0.075	0.17	0.02	0.025	0.055	0.03	0.01	0.01	0.015				
9/02/71																			
2/26/71		0.015	0.055	0.005	0.035	0.01	0.02	0.04	0.02				0.015	0.02	0.12				
5/02/72		0.01	0.00	0.00	0.025	0.00	0.00			0.00	0.01	0.00	0.00	0.00					
6/19/72	0.015	0.02	0.015	0.01	0.055	0.08	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.03	0.00				
7/25/72	0.005	0.01		0.00	0.075	0.01	0.01	0.005	0.00	0.005	0.005	0.01	0.01	0.01	0.01				
8/14/72	0.02	0.03		0.005	0.10	0.03	0.015	0.01	0.00	0.005	0.01	0.02	0.00	0.00	0.01				
8/28/72	0.01	0.01		0.005	0.05	0.01	0.02	0.01	0.00	0.00	0.005	0.01	0.00	0.00	0.00				
9/12/72	0.01	0.01		0.00	0.045	0.005	0.02	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00				
9/27/72	0.01	0.01		0.00	0.05	0.005	0.01	0.005	0.00	0.005	0.01	0.01	0.00	0.00	0.00				
10/10/72	0.01	0.015		0.005	0.09	0.005	0.015	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
10/26/72	0.01	0.03		0.005	0.07	0.01	0.005	0.005	0.00	0.005	0.005	0.01	0.00	0.00	0.005				
11/27/72																			
12/26/72																			
1/11/73																			
2/13/73	0.045	0.015		0.015	0.03	0.005	0.025	0.005	0.00				0.00	0.00	0.01				
3/08/73																			
3/26/73																			
3/29/73		0.01		0.01	0.02	0.01	0.02	0.01		0.01		0.01	0.01	0.01	0.015				
4/02/73																			
4/09/73																			
4/12/73	0.005	0.03		0.02	1.8	0.53		0.17		0.17	0.22	0.20	0.15	0.22	1.30				
4/16/73																			
4/26/73		0.015		0.015	0.03	0.01	0.01	0.01		0.01	0.005	0.01	0.01	0.005	0.005				
5/14/73		0.03	0.01	0.015	0.015	0.01	0.01	0.01		0.02	0.01	0.02	0.015	0.02	0.02				
5/29/73	0.01	0.02	0.015	0.02	0.10	0.015	0.02	0.01		0.01	0.015	0.01	0.01	0.01	0.01				
6/11/73	0.035	0.03	0.03	0.025	0.04	0.01	0.02	0.01		0.01	0.01	0.01	0.02	0.01	0.02				
6/25/73	0.015	0.02	0.01	0.01	0.06	0.01	0.01	0.015		0.015	0.01	0.015	0.015	0.01	0.01				
7/09/73		0.08	0.03	0.01	0.06	0.01	0.015	0.01		0.015	0.015	0.015	0.015	0.015	0.01				
7/23/73		0.08	0.035	0.033	0.098	0.025	0.047	0.03		0.03	0.013	0.013	0.02	0.015	0.015				
8/06/73	0.015	0.02	0.01	0.01	0.075	0.015	0.01	0.005	0.015	0.025	0.025	0.02	0.005	0.015	0.03				
8/20/73	0.01	0.025	0.01	0.01	0.07	0.015	0.015	0.02	0.025	0.03	0.015	0.02	0.03	0.015	0.02				
9/20/73	0.015	0.03	0.01	0.01		0.015	0.02	0.005	0.015	0.01	0.01	0.01	0.01	0.005	0.005				
10/15/73	0.01	0.015	0.015	0.01		0.01	0.01	0.015	0.01	0.01	0.01	0.015	0.01	0.01	0.005				
1/04/74							0.015												
1/09/74			0.01			0.01		0.03					0.045	0.02	0.02				
2/12/74																			
3/13/74																			
5/07/74		0.035	0.015	0.015	0.07	0.015		0.01		0.015	0.015	0.01	0.03	0.015	0.01				
7/09/74		0.04	0.015	0.015	0.07	0.015	0.03	0.015	0.015	0.02	0.01	0.015	0.015	0.015	0.02				
7/30/74		0.03	0.025	0.015	0.055	0.025	0.035	0.025	0.025	0.03	0.02	0.025	0.34	0.045	0.025				
8/19/74		0.025	0.025	0.015	0.05	0.02	0.045	0.015	0.015	0.02	0.025	0.025	0.04	0.025	0.02				
9/09/74		0.03	0.02	0.015	0.06	0.015		0.015		0.02	0.02	0.015	0.025	0.02	0.015				
10/07/74		0.045	0.02	0.02	0.065	0.02		0.045		0.025	0.015	0.015	0.015	0.01	0.01				
10/21/74		0.03	0.015	0.02	0.055	0.01		0.01		0.01	0.01	0.01	0.015	0.015	0.01				
11/04/74		0.04,	0.01	0.005	0.055	0.01	0.02	0.005		0.01	0.015	0.01	0.015	0.01	0.01				
11/25/74		0.035	0.01	0.01	0.065	0.01	0.02	0.1		0.015	0.02	0.01	0.025	0.01	0.015				
12/16/74		0.01	0.01	0.01	0.055	0.01	0.02	0.015		0.01	0.01	0.01	0.015	0.01	0.015				
1/07/75				0.01	0.015	0.015	0.025	0.005					0.065	0.01	0.02				
1/29/75		0.015	0.015	0.01	0.02	0.005	0.02	0.01			0.005	0.01	0.01	0.01	0.01				
2/19/75				0.015	0.06	0.015	0.02	0.01					0.01	0.015					
3/05/75		0.03	0.02	0.015	0.06	0.01	0.02	0.015					0.01	0.01	0.015				
3/25/75				0.01			0.01	0.01					0.02	0.01	0.01		0.02	0.015	0.01
4/07/75		0.02	0.01	0.005	0.065	0.01	0.02	0.01	0.005				0.005	0.005	0.005	0.02	0.14	0.02	0.01
4/29/75		0.035	0.015	0.015	0.075	0.02	0.03	0.01					0.015	0.02	0.01	0.01	1.44	0.01	0.01
5/19/75		0.015	0.01	0.015	0.065	0.01	0.02	0.01		0.015	0.01	0.01	0.01	0.01	0.01	0.015	0.74	0.02	0.01
6/17/75		0.02	0.015	0.01	0.02	0.005	0.015	0.005		0.01	0.005	0.005	0.015	0.005	0.01	0.01	0.02	0.01	0.01
7/07/75		0.02	0.01	0.015	0.06	0.01	0.04	0.01		0.01	0.01	0.01	0.005	0.005	0.01	0.015	0.01	0.02	0.015
7/21/75		0.015	0.015	0.01	0.03	0.01	0.04	0.015		0.02			0.02	0.02	0.025	0.02	0.02	0.015	0.015
8/11/75		0.015	0.01	0.01	0.06	0.01	0.035	0.01		0.015	0.015	0.015	0.02	0.01	0.01	0.015	0.03	0.025	0.01
9/02/75		0.025	0.015	0.02	0.07	0.02	0.01	0.015		0.01			0.03	0.015	0.015	0.015	0.04	0.025	0.02
9/22/75		0.02	0.01	0.01	0.04	0.01	0.05	0.01		0.01	0.01	0.01	0.015	0.015	0.015	0.02	0.055	0.02	0.01
10/07/75		0.03	0.01	0.015	0.065	0.015	0.045	0.01		0.015			0.02	0.01	0.015	0.02	0.045	0.025	0.01
10/27/75		0.03	0.02	0.01	0.06	0.01	0.045	0.01		0.015			0.015	0.01	0.01	0.015	0.035	0.015	0.01
11/24/75		0.03	0.015	0.01	0.06	0.015	0.025	0.015		0.015			0.055	0.01	0.015	0.015	0.05	0.025	0.015
12/16/75		0.035	0.01	0.015	0.045	0.005	0.025	0.01					0.065	0.015	0.015	0.025	0.045	0.025	0.01
1/14/76			0.025	0.015	0.055		0.035	0.015					0.07	0.015	0.015		0.03	0.02	0.015
2/10/76		0.045	0.02	0.02	0.075	0.03	0.045	0.035		0.03	0.035	0.03	0.025	0.04	0.025	0.035	0.04	0.035	0.04
3/9/76		0.03	0.04	0.03		0.015	0.05	0.025					0.01	0.01	0.01		0.16	0.025	0.02
3/30/76		0.035	0.01	0.01	0.035	0.005	0.03	0.01		0.02	0.02	0.01	0.01	0.015	0.04	0.015	0.17	0.03	0.01
5/11/76		0.045	0.025	0.025	0.065	0.03	0.05	0.035		0.03	0.035	0.03	0.025	0.035	0.035	0.035	0.255	0.055	0.035
6/02/76				0.045	0.08	0.04	0.055	0.045					0.16	0.045		0.04	0.055	0.055	0.035
6/22/76		0.045	0.045	0.03	0.065	0.045	0.075	0.035		0.045			0.06	0.03	0.035	0.04	0.05	0.055	0.04
7/13/76		0.055	0.045	0.045	0.075	0.04	0.095	0.045		0.05	0.05	0.05	0.055	0.035	0.04	0.45	0.06	0.045	0.045
8/03/76		0.04	0.04	0.03	0.06	0.005	0.065	0.025		0.03			0.025	0.015	0.03	0.035	0.04	0.04	0.03
9/8/76		0.06	0.035	0.025	0.075	0.035	0.07	0.03		0.035	0.045		0.045	0.025	0.035	0.03	0.065	0.065	0.055
9/29/76		0.03	0.01	0.015	0.055	0.02	0.045	0.015		0.15	0.02		0.015	0.02	0.03	0.04	0.07	0.035	0.02
10/20/76		0.05	0.025	0.035	0.06	0.025	0.035	0.02		0.015	0.02		0.015	0.015	0.015	0.07	0.125	0.025	0.02

as the almost undiluted effluent recovered from wells 5, 9, 12E, 12W, 17 and 18 showed no increments of phosphorus over background levels.

Evidence to date, therefore, still is negative for addition of irrigation phosphorus to ground waters in the summer irrigation site. Also, essentially no phosphorus has been added to the surface waters leaving the site via ditches 1 and 2. Even though a nominal concentration level of phosphorus was detected in runoff of the 76 and 102 mm per week areas, the amount of phosphorus leaving the site was extremely low since the volume of direct runoff was very low.

The nitrate nitrogen concentrations for 1975 and 1976 (Table 22) continue to reflect the pre-irrigation background levels displayed during the years 1971 and 1972, except for wells 5, 9, 12E and 12W. The nitrate concentrations in these wells remained appreciably lower in the last two years than their previous background levels, which may be due to the continuously higher water table since irrigation began. This higher water table prevents appropriate aeration for the production of nitrate from organic matter existing upgradient from the wells, or it may be due to the increased use of nitrate by the better vegetative cover on the area.

Wells 3, 4, 10W and 13 indicate the continuing background levels of nitrate nitrogen which ranged from 0.01 to 6.0 mg/l throughout the project to-date. It is interesting to note, however, that the levels for wells 3 and 13 most often ranged from 1 to 6 mg/l while those of wells 4 and 10W ranged only from 0.01 to 0.2 mg/l. This is another indication of the effect of the production of nitrate from organic matter existing up-gradient from the wells.

Ammonia nitrogen concentrations for all wells during 1975 and 1976 (Table 23) also continue to follow patterns established prior to the start of wastewater irrigation, except for well 12E. In this well during the late summer months, ammonia nitrogen levels ranged up to 25 mg/l; whereas in all other wells, it rarely was over 3 mg/l. The range of high ammonia nitrogen levels of well 12E over the past four years were: 1973 from 13 to 25 mg/l, 1974 from 12 to 24 mg/l, 1975 from 6 to 18 mg/l, and 1976 from 1 to 4 mg/l.

Before irrigation, little ammonia was measured in well 12E, but appreciable and fluctuating amounts of nitrate were recorded. This indicated an adequate supply of organic matter and appropriate aeration for the production of nitrate up-gradient from the well screens. After irrigation developed a sufficient increase in ground water level (July, 1973), no major production of nitrate occurred. This high water table produced anaerobic conditions, and the production of ammonia in well 12E began July, 1973. The decrease in ammonia production over the past two years could be due to a decreased organic matter supply or to the use of the ammonia nitrogen by increased crop growth.

The ranges in levels of nitrogen forms added by wastewater irrigation over the past four years were: 0.1 to 0.3 mg/l for nitrate nitrogen, 0.1 to 0.4 mg/l for ammonia nitrogen, and 1.2 to 4.6 mg/l for total Kjeldahl nitrogen These quantities are no higher than nitrogen levels measured in the ground water under the summer irrigation site and also were so small that crop responses showed nitrogen deficiencies as discussed in Section 6. The present data, however, would serve well as background information for determining degrees of renovation under nutrient levels associated with adequate crop fertilization.

TABLE 22. AMMONIA NITROGEN IN GROUND WATER
(mg/1)

	Well number																		
	Summer irrigation site																		
Date	1	3	4	5	6	7	8	9	10E	10W	11E	11W	12E	12W	13	16	17	18	19
12/24/70	0.1	0.2	0.5	0.00	0.1	1.6	0.5	0.6	0.8	0.1	0.0	0.00		0.00	0.1				
1/04/71																			
3/06/71	0.2	0.1	0.7	0.01	1.2	0.15	2.0	0.05	0.10	0.02	0.04	0.00	0.05	0.05	0.00				
8/06/71	2.3	0.0	0.0	0.46	1.04	0.3	1.7	2.2	0.00	0.00	0.00	0.00	0.00	0.0	0.00				
9/02/71																			
2/26/72		0.08	0.33	0.08	0.90	0.05	1.02	1.40	0.10				0.00	0.30	0.30				
5/02/72		0.05	1.86	0.17	1.36	0.17	1.36			0.1	0.08	0.08	0.8	0.1					
6/19/72	1.01	0.48	4.31	0.32	2.34	0.30	2.18	0.24	0.30	0.17	0.32	0.17	0.11	0.30	0.96				
7/25/72	0.22	0.43		0.19	3.94	0.32	1.9	0.19	0.22	0.17	0.25	0.22	0.27	0.14	0.17				
8/14/72	0.06	0.09		0.06	2.27	0.27	2.25	0.11	0.17	0.06	0.40	0.05	0.25	0.17	0.11				
8/28/72	0.3	0.17		0.17	1.69	0.53	2.0	0.27	0.17	0.17	0.22	0.17	0.17	0.0	0.17				
9/12/72	0.27	0.38		0.17	1.71	0.43	2.03	0.20	0.20	0.15	0.17	0.22	0.22	0.08	0.22				
9/27/72	0.27	0.35		0.17	2.12	0.43	2.55	0.30	0.22	0.17	0.25	0.30	0.35	0.11	0.17				
10/10/72	0.20	0.32		0.17	1.63	0.30	2.15	0.20	0.20	0.11	0.32	0.15	0.17	0.06	0.22				
10/26/72	0.27	0.50		0.27	1.93	0.43	1.95	0.17	0.30	0.17	0.35	0.27	0.25	0.06	0.30				
11/27/72																			
12/26/72																			
1/11/73																			
1/31/73																			
2/13/73	1.06	0.48		0.27	2.5	0.38	2.18	0.27	0.2				0.20	0.20	0.35				
3/08/73																			
3/26/73																			
3/29/73		0.25		0.20	0.85	0.35	1.95	0.35		0.32		0.20	0.25	0.22	0.30				
4/2/73																			
4/9/73																			
4/12/73	0.17	0.22		0.15	1.53	0.25		0.11		0.15	0.11	0.17	0.15	0.11	0.27				
4/16/73																			
4/26/73		0.27		0.20	1.35	0.22	1.65	0.15		0.17	0.17	0.11	0.17	0.11	0.32				
5/14/73		0.3	2.43	0.22	1.25	0.27	1.74	0.22		0.15	0.22	0.22	0.22	0.17	0.27				
5/29/73	0.22	0.38	2.21	0.27	1.66	0.27	1.72	0.22		0.15	0.25	0.22	0.38	0.15	0.30				
6/11/73	0.22	0.32	2.21	0.25	1.40	0.38	1.92	0.22		0.17	0.22	0.22	0.38	0.17	1.09				
6/25/73	0.17	0.22	1.26	0.22	0.77	0.19	1.26	0.16		0.16	0.26	0.17	0.25	0.15	0.44				
7/09/73		0.40	3.45	0.27	2.35	0.40	1.88	0.22		0.17	0.22	0.22	0.58	0.20	0.42				
7/09/73		0.30	2.03	0.27	1.30	0.40	1.60	0.22		0.17	0.22	0.20	0.58	0.20	0.38				
7/23/73		0.35	3.37	0.20	1.60	0.40	2.25	0.27		0.17	0.63	0.35	7.40	0.22	0.30				
7/23/73		0.32	2.43	0.11	1.48	0.27	2.18	0.17		0.15	0.16	0.22	7.64	0.22	0.22				
8/6/73	0.40	0.27	3.43	0.27	1.60	0.40	1.87	0.25	0.11	0.27	0.17	0.22	22.5	0.27	0.48				
8/20/73	0.11	0.06	3.22	0.22	1.58	0.27	2.06	0.17	0.06	0.02	0.00	0.00	24.3	0.40	0.17				
8/06/73	0.30	0.27	2.31	0.11	1.50	0.27	1.85	0.09	0.11	0.15	0.11	0.09	18.9	0.27	0.17				
8/20/73	0.06	0.06	3.22	0.22	1.53	0.22	2.18	0.11	0.06	0.005	0.00	0.00	24.0	0.20	0.15				
9/20/73	0.22	0.27	3.94	0.22	0.90	0.30	1.88	0.17	0.11	0.17	0.17	0.17	24.6	0.15	0.20				
9/20/73	0.17	[illegible]	3.46	0.15	9.90	0.22	1.88	0.15	0.11	0.15	0.15	0.15	24.6	0.15	0.15				
10/15/73	0.15	0.20	3.82	0.27	1.11	0.38	2.43	0.22	0.17	0.11	0.15	0.17	12.7	0.09	0.17				
10/15/73	0.15	0.20	3.46	0.27	1.11	0.38	1.90	0.22	0.17	0.11	0.09	0.15	12.7	0.07	0.11				
1/04/74																			
1/09/74			4.13			0.33	1.70	0.10					8.20	0.12	0.12				
2/12/74																			
3/13/74																			
5/07/74		0.00	1.58	0.02	0.93	0.02		0.01		0.01	0.005	0.005	2.50	0.005	0.005				
7/09/74		0.22	1.93	0.20	0.82	0.13	2.03	0.15	0.08	0.05	0.03	0.08	0.68	0.15	0.13				
7/30/74		0.28	1.33	0.18	0.93	0.18	2.10	0.18	0.08	0.08	0.08	0.03	0.03	0.18	0.22				
8/19/74		0.03	1.03	0.08	0.50	0.13	1.94	0.08	0.08	0.08	0.03	0.03	13.0	0.18	0.08				
9/09/74		0.22	1.12	0.12	0.82	0.18		0.08		0.03	0.08	0.11	12.8	0.12	0.08				
10/07/74		0.05	1.30	0.20	1.14	0.05		0.05		0.10	0.10	0.08	24.0	0.10	0.15				
10/21/74		0.25	1.25	0.15	0.92	0.20		0.10		0.13	0.80	0.08	12.0	0.13	0.10				
11/04/74		0.32	1.03	0.20	1.03	0.20	1.65	0.20		0.15	0.15	0.15	12.0	0.15	0.20				
11/25/74		0.05	0.92	0.05	1.4	0.05	1.39	0.10		0.10	0.10	0.10	6.0	0.10	0.15				
12/16/74		0.22	1.22	0.27	1.06	0.17	1.90	0.22		0.60	0.08	0.10	5.3	0.15	0.20				
1/07/75				0.20	1.32	0.12	2.12	0.12					1.12	0.40	0.12				
1/29/75			1.44	0.03	0.58	0.03	2.60	0.12			0.12	0.10	1.20	0.03	0.12				
2/19/75				0.1	1.1	0.18	1.9	0.03					0.7	0.05					
3/05/75		0.05	1.0	0.05	0.89	0.12	1.7	0.05					0.89	0.05	0.09				
3/25/75				0.29			1.69	0.1					0.42	0.05	0.12		0.12	0.32	0.18
4/07/75		0.03	1.0	0.01	1.12	0.09	1.6	0.09	0.12				0.12	0.09	0.09	0.19	0.03	0.4	0.19
4/29/75		0.23	1.02	0.23	0.93	0.18	1.65	0.03					0.08	0.03	0.13	0.23	0.13	0.18	0.13
5/19/75		0.1	0.93	0.12	0.88	0.12	1.49	0.03		0.03	0.01	0.01	0.15	0.03	0.09	0.12	0.03	0.62	0.18
6/17/75		0.18	0.89	0.32	0.83	0.18	1.83	0.12		0.08	0.08	0.08	0.12	0.12	0.12	0.28	0.18	0.39	0.12
7/07/75		0.22	1.89	0.28	0.69	0.22	2.29	0.12		0.08	0.08	0.08	0.48	0.18	0.12	0.22	0.15	0.39	0.18
7/21/75		0.03	0.58	0.03	1.03	0.12	1.9	0.08		0.08			0.22	0.08	0.12	0.08	0.03	0.22	0.12
8/11/75		0.21	0.88	0.28	1.53	0.39	2.19	0.12		0.12	0.02	0.02	0.52	0.08	0.18	0.12	0.12	0.33	0.12
9/02/75		0.39	1.02	0.28	1.53	0.43	2.0	0.19		0.08			17.5	0.39	0.2	0.43	0.39	0.48	0.22
9/22/75		0.39	0.98	0.43	1.33	0.28	2.23	0.12		0.09	0.09	0.12	5.86	0.22	0.18	0.39	0.22	0.39	0.18
10/07/75		0.12	0.89	0.08	0.93	0.18	1.69	0.08		0.05			10.65	0.23	0.08	0.35	0.21	0.35	0.12
10/27/75		0.12	1.08	0.02	0.82	0.29	1.69	0.12		0.12			10.65	0.08	0.18	0.35	0.35	0.39	0.22
11/24/75		0.03	0.98	0.12	1.33	0.09	1.49	0.03		0.03			8.15	0.03	0.08	0.12	0.05	0.12	0.08
12/16/75		0.39	0.98	0.28	1.29	0.28	1.9	0.18					5.6	0.1	0.15	0.32	0.18	0.32	0.28
1/14/76			0.98	0.28	0.68		1.39	0.12					3.1	0.12	0.15		0.39	0.42	0.42
2/10/76		0.20	0.82	0.48	0.88	0.20	1.63	0.15		0.08	0.05	0.10	0.43	0.05	0.05				
3/9/76		0.12	0.72	0.08		0.08	2.13	0.10					0.1	0.02	0.08		0.53	0.42	0.20
3/30/76		0.28	0.82	0.28	0.52	0.32	2.24	0.12		0.02	0.02	0.08	0.32	0.05	0.22	0.35	0.08	0.58	0.48
5/11/76		0.3	0.93	0.18	0.72	0.22	1.94	0.08		0.06	0.06	0.02	0.1	0.08	0.18	0.18	0.22	0.39	0.22
6/02/76				0.17	0.58	0.22	1.93	0.12					0.28	0.05		0.28	0.17	0.22	0.22
6/22/76		0.05	0.52	0.12	0.78	0.39	2.29	0.22		0.22			0.08	0.22	0.28	0.28	0.28	0.12	0.12
7/13/76		0.22	0.72	0.1	0.72	0.12	2.5	0.08		0.05	0.08	0.05	0.08	0.12	0.12	0.22	0.19	0.32	0.19
8/3/76		0.23	0.72	0.2	0.93	0.18	2.28	0.18		0.08			0.32	0.12	0.08	0.23	0.23	0.43	0.23
9/8/76		0.22	0.68	0.29	0.88	0.05	1.9	0.13		0.05	0.08		2.5	0.05	0.13	0.18	0.13	0.22	0.08
9/29/76		0.03	.58	.03	1.13	.18	1.9	0.08		0.08	0.05		1.25	0.08	0.08	0.18	0.29	0.32	0.22
10/20/76		0.23	0.68	0.18	0.72	0.18	1.69	0.12		0.01	0.02		3.5	0.08	0.05	0.28	0.28	0.26	0.18
11/8/76				0.4	0.88	0.22	1.62	0.12					1.62	0.08		0.22	0.03	0.28	0.22

TABLE 23. NITRATE-NITROGEN IN GROUND WATER
(mg/l)

Date	Well number																		
	Summer irrigation site																		
	1	3	4	5	6	7	8	9	10E	10W	11E	11W	12E	12W	13	16	17	18	19
12/24/70	0.00	0.0	0.00	0.00	0.00	0.00	0.00	1.3	0.42	0.00	0.00		22.0	1.9	0.58				
1/04/71																			
3/06/71	0.00	1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.9	1.0	4.4				
8/06/71	0.00	1.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.98	1.36	0.58				
9/02/71																			
2/26/72		0.21	0.10	3.6	0.10	0.005	0.07	0.07	0.05				4.8	1.2	1.85				
5/02/72		2.6	0.12	4.8	0.03	0.00	0.00			0.00	0.00	0.00	4.6	6.2					
6/19/72	0.01	1.69	0.06	2.61	0.11	0.01	0.03	5.6	0.09	0.00	0.00	0.00	9.93	11.9	2.66				
7/25/72	0.03	2.34		2.24	0.34	0.06	0.06	2.34	0.03	0.03	0.03	0.01	1.56	1.0	1.72				
8/14/72	0.00	2.37		1.84	0.13	0.01	0.03	2.77	0.07	0.01	0.01	0.00	5.28	8.56	1.2				
8/28/72	0.01	1.29		1.5	0.09	0.03	0.03	3.6	0.04	0.01	0.00	0.00	5.8	12.0	0.97				
9/12/72	0.01	2.15		1.29	0.13	0.03	0.06	1.81	0.075	0.03	0.03	0.03	5.2	10.0	0.33				
9/27/72	0.03	2.4		3.1	0.19	0.06	0.06	0.07	0.06	0.03	0.01	0.01	9.36	5.52	0.13				
10/10/72	0.01	0.28		4.86	0.17	0.06	0.03	0.88	0.01	0.01	0.00	0.00	7.24	5.04	0.13				
10/26/72	0.01	0.82			0.21	0.07	0.05	0.60	0.03	0.01	0.01	0.01	2.88	3.28	0.13				
11/27/72																			
12/26/72																			
11/11/73																			
1/31/73																			
2/13/73	0.17	2.62		4.0	0.16	0.06	0.06	2.43	0.06				8.48	8.48	4.42				
3/08/73																			
3/26/73																			
3/29/73		1.86		3.0	0.05	0.00	0.00	1.45		0.00		0.00	6.95	5.52	5.84				
4/02/73																			
4/09/73																			
4/12/73	0.03	1.88		2.76	0.79	0.45		1.13		0.03	0.015	0.015	13.7	12.9	5.65				
4/16/73																			
4/26/73		0.97		2.0	0.03	0.015	0.03	0.57		0.0	0.0	0.00	17.0	16.2	6.45				
5/14/73		2.52	0.09	1.85	0.05	0.0	0.015	0.21		0.0	0.0	0.00	24.8	12.8	4.4				
5/29/73	0.03	1.26	0.03	1.14	0.06	0.015	0.015	0.03		0.0	0.0	0.00	16.5	25.0	4.0				
6/11/73	0.00	2.27	0.06	1.4	0.4	0.0	0.0	0.015		0.0	0.0	0.00	0.6	20.3	2.24				
6/25/73	0.00	2.49	0.06	1.0	0.03	0.0	0.0	0.0		0.0	0.0	0.00	1.6	25.8	1.76				
7/09/73		2.49	0.03	0.63	0.01	0.0	0.0	0.0		0.0	0.0	0.00	0.13	0.7	2.27				
7/23/73		2.82	0.01	0.69	0.03	0.0	0.0	0.0		0.0	0.0	0.00	0.03	0.75	2.82				
8/06/73	0.03	2.52	0.06	0.38	0.06	0.0	0.0	0.06	0.0	0.0	0.0	0.00	0.06	0.76	2.61				
8/20/73	0.01	1.5	0.06	0.14	0.04	0.01	0.03	0.0	0.0	0.0	0.0	0.00	0.07	1.0	1.36				
9/20/73	0.03	3.24	0.00	0.00	0.01	0.0	0.0	0.37	0.0	0.0	0.0	0.00	0.09	0.19	3.32				
10/15/73	0.03	2.76	0.00	0.00	0.03	0.0	0.015	0.29	0.0	0.0	0.0	0.00	0.15	3.44	2.06				
1/04/74																			
1/09/74			0.27			0.015	0.015	0.32					0.03	0.52	0.72				
2/12/74																			
3/13/74																			
5/07/74		2.4	0.11	0.06	0.16	0.01		0.46		0.04	0.13	0.02	0.02	0.10	6.9				
7/09/74		0.21	0.13	0.04	0.29	0.04	0.07	0.1	0.0	0.0	0.0	0.0	0.21	0.07	4.1				
7/30/64		0.72	2.09	1.39	2.0	1.0	2.35	0.69	0.62	0.52	0.58	0.72	1.42	1.0	0.58				
8/19/74		2.9	0.00	0.00	0.12	0.0	0.05	0.44	0.0	0.0	0.0	0.0	0.28	3.36	3.36				
9/09/74		2.6	0.01	0.05	0.14	0.02		0.25		0.0	0.0	0.0	0.21	1.76	0.015				
10/07/74		2.8	0.05	0.05	0.2	0.05		0.02		0.0	0.02	0.05	0.2	2.3	2.5				
10/21/74		2.3	0.20	0.1	0.3	0.2		0.1		0.08	0.1	0.08	0.3	0.95	1.6				
11/04/74		2.55	0.25	0.25	0.3	0.28	0.28	0.2		0.2	0.22	0.2	0.32	1.2	1.16				
11/25/74		2.16	0.25	0.2	0.27	0.2	0.26	0.2		0.15	0.15	0.15	0.28	1.13	0.43				
12/16/74		2.6	0.15	0.1	0.15	0.05	0.05	0.1		0.05	0.05	0.05	0.25	1.50	0.38				
1/07/75				0.1	0.15	0.1	0.13	0.2					0.54	1.04	0.44				
1/29/75			0.1	0.1	0.15	0.08	0.12	0.2			0.00	0.05	0.3	0.62	1.86				
2/19/75				0.1	0.15	0.1	0.13	0.3					0.32	0.63					
3/05/75		2.4	0.07	0.07	0.15	0.07	0.1	0.36					0.21	0.6	2.6				
3/25/75				0.1			0.13	0.3					0.36	0.6	5.05		0.2	0.1	0.05
4/07/75		2.24	0.1	0.05	0.13	0.08	0.1	0.34	0.05				0.46	0.5	4.32	0.1	0.43	0.08	0.08
4/29/75		2.28	0.12	0.1	0.18	0.1	0.07	0.27					0.51	0.62	4.92	0.18	0.25	0.13	0.07
5/19/75		2.96	0.1	0.07	0.21	0.1	0.1	0.25		0.07	0.04	0.07	0.4	0.49	3.2	0.1	0.74	0.1	0.1
6/17/75		0.52	0.1	0.07	0.21	0.1	0.12	0.34		0.07	0.1	0.1	0.12	0.37	2.52	0.16	0.12	0.12	0.14
7/07/75		2.52	0.13	0.11	0.13	0.08	0.13	0.11		0.08	0.05	0.05	0.11	0.29	5.48	0.95	0.24	0.13	0.08
7/21/75		2.48	0.1	0.1	0.18	0.1	0.12	0.28		0.05			0.01	0.32	3.08	0.16	0.1	0.1	0.1
8/11/75		2.76	0.05	0.05	0.18	0.08	0.12	0.12		0.05	0.02	0.02	0.08	0.57	3.12	0.14	0.10	0.10	0.08
9/02/75		1.24	0.11	0.11	0.18	0.11	0.13	0.18		0.08			0.21	1.1	1.36	0.11	0.13	0.11	0.1
9/22/75		1.39	0.13	0.13	0.18	0.13	0.18	0.1		0.1	0.1	0.1	0.21	1.29	1.1	0.18	0.13	0.11	0.11
10/07/75		2.1	0.13	0.11	0.21	0.11	0.38	0.11		0.07			0.21	0.54	1.58	0.13	0.11	0.11	0.1
10/27/75		2.02	0.16	0.11	0.11	0.1	0.13	0.1		0.07			0.21	1.26	1.01	0.11	0.11	0.1	0.07
11/24/75		2.02	0.13	0.13	0.18	0.11	0.13	0.1		0.07			0.25	1.8	0.63	0.11	0.16	0.11	0.1
12/16/75		1.08	0.1	0.08	0.13	0.1	0.11	0.11					0.21	1.82	1.08	0.08	0.08	0.08	0.08
1/14/76			0.12	0.08	0.10		0.12	0.13					0.51	2.05	0.77		0.12	0.08	0.08
2/10/76		2.0	0.12	0.12	0.12	0.1	0.12	0.23		0.04	0.08	0.08	0.56	1.23	0.94	0.12	0.1	0.1	0.08
3/9/76		1.52	0.10	0.10		0.08	0.11	0.18					0.59	1.21	3.36		0.48	0.10	0.08
3/30/76		1.71	0.10	0.10	0.10	0.08	0.11	0.32		0.05	0.05	0.08	0.54	1.18	2.3	1.09	0.59	0.10	0.05
5/11/76		1.59	0.18	0.11	0.13	0.1	0.13	0.18		0.05	0.05	0.05	0.92	1.45	2.44	0.74	0.29	0.1	0.07
6/02/76				0.13	0.13	0.1	0.15	0.13					0.4	1.48		0.3	0.11	0.11	0.1
6/22/76		1.67	0.13	0.11	0.13	0.1	0.18	0.1		0.1			0.18	0.77	2.3	1.05	0.13	0.13	0.1
7/13/76		1.81	0.16	0.12	0.12	0.1	0.13	0.16		0.05	0.07	0.05	0.12	0.4	2.8	0.61	0.13	0.13	0.1
8/3/76		2.02	0.15	0.15	0.15	0.11	0.15	0.21		0.1			0.13	1.45	2.8	0.32	0.11	0.11	0.1
9/8/76		2.12	0.07	0.11	0.15	0.1	0.13	0.05		0.05	0.02		0.11	2.22	2.68	1.13	0.18	0.05	0.02
9/29/76		2.14	0.05	0.07	0.1	0.07	0.11	0.1		0.02	0.02		0.07	3.45	3.0	0.07	0.1	0.05	0.05
10/20/76		2.56	0.07	0.07	0.11	0.07	0.1	0.07		0.04	0.02		0.11	2.28	1.38	0.07	0.1	0.05	0.05
11/8/76				0.11	0.13	0.13	0.18	0.13			0.04		0.18	2.44	0.13	0.28	0.13	0.11	

SECTION 8

INSECTS INDIGENOUS TO WASTEWATER TREATMENT SITES

A research program to evaluate the entomological problems associated with oxidation pond-spray irrigation facilities was included in the overall Belding project. The primary emphasis of this program was to locate and characterize the potential insect breeding habitats that existed and that later developed in the total project area. Particular attention was to be focused on insects which serve as human or animal pests or vectors of disease, and to determine methods for their control. This report presents the essence of the findings to date, and excerpts freely from project reports prepared by the staff member directing the entomological study.

PROCEDURE

Since this project was concerned primarily with insect species that may serve as human or animal pests or vectors of pathogenic organisms, the sampling techniques utilized were those that are standard for these groups of insects. Aquatic stages were sampled with a one-pint enamel dipper with dips being made at selected localities along the margins of each stabilization pond cell, localized water accumulations in the summer irrigation site, and the length of ditches 3 and 4 located adjacent to cells 2, 3, 4 and 5 (Figure 12).

The immature aquatic stages of biting insects are restricted to specific types of habitats along the margins of ponds and streams rather than being randomly distributed throughout the entire water body or along its periphery. In general, these habitats are characterized as having emergent vegetation that provides partial to complete shade and protection from the wind, a water depth of 25 to 250 mm, and little or no wave action or current. The specific locations of this type of habitat in the study site vary markedly with fluctuations in water levels, the height of marginal vegetation, and whether or not marginal vegetation is removed or allowed to accumulate in the water following routine mowing operations. Because of this, no fixed sampling sites were established but examinations were made at those locations where the insects were most likely to occur. While the total numbers of samples varied according to conditions that existed on any specific day of study, a sufficient number of dips was taken to assure obtaining an adequate representation of the desired insect groups. At least three replicate dips were made at each location sampled and the numbers of insects in each dip were recorded. Representative samples of the insect groups of concern were removed from the sample, placed in vials of 70 percent alcohol, and taken to the laboratory for microscopic examination and identification. In 1974, selected specimens also were taken to the laboratory

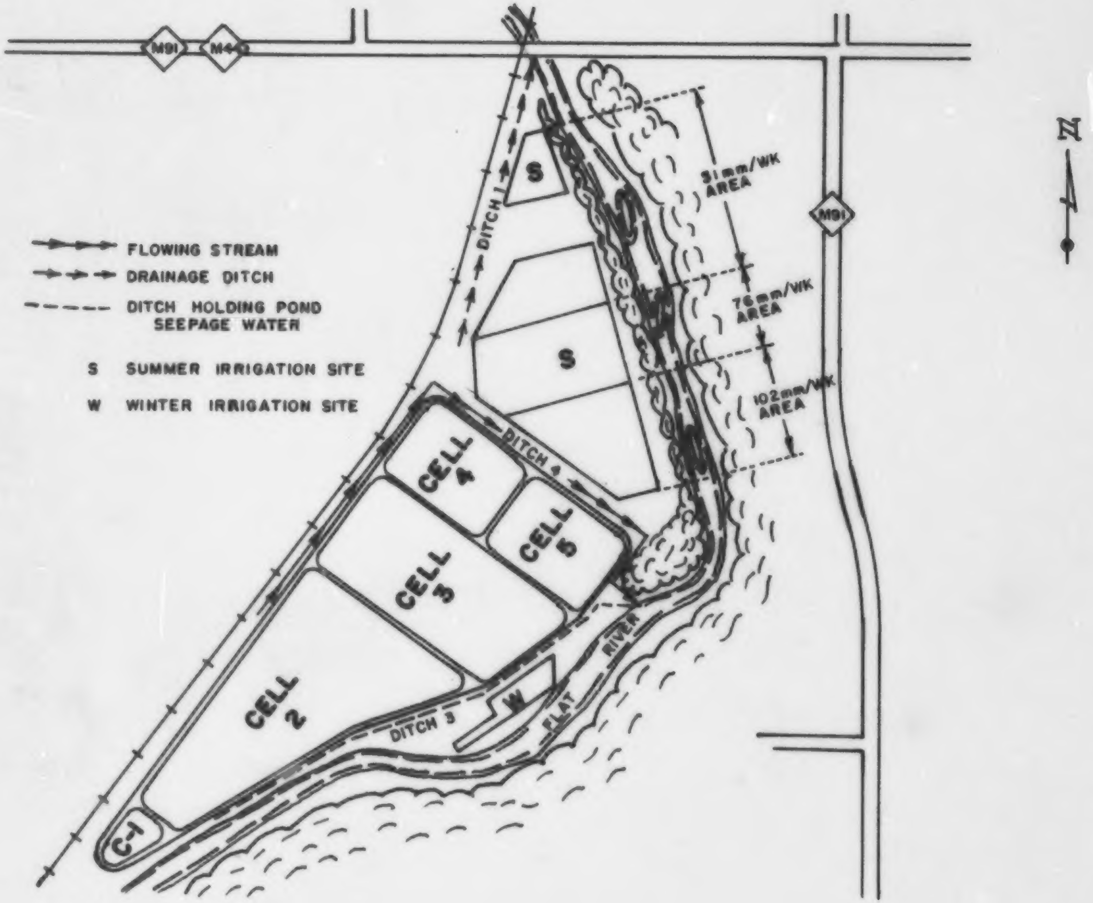
M91
M44
M91
FLOWING STREAM
DRAINAGE DITCH
DITCH HOLDING POND SEEPAGE WATER
S SUMMER IRRIGATION SITE
W WINTER IRRIGATION SITE
N
S
S
W
DITCH 1
DITCH 4
DITCH 3
FLAT RIVER
CELL 2
CELL 3
CELL 4
CELL 5
C-1
31mm/WK AREA
76mm/WK AREA
102mm/WK AREA

Figure 12. Map depicting entomological study area.

and reared to mature larval or adult stages. Immature mosquitoes normally can be identified to genus in any stage of development, but identification of species usually requires fourth stage larvae. For this reason, prior to 1974, specific determinations were made only when fourth stage larvae were collected. Identifications of other immature stages were made only as to genus.

Adult biting insects vary markedly in their behavior and required a variety of techniques in sampling the populations at Belding. Most Culex mosquito adults prefer to rest in vegetation during the day and become active and seek blood meals only from dusk to dawn. Adult Culex collections were made after disturbing vegetation along the pond and stream margins. Some Aedes mosquitoes usually are restricted to wooded areas but may also rest in vegetation adjacent to these sites. These species frequently attack any suitable host that approaches their resting sites at any time of day or night. Surveys for adult Aedes mosquitoes were made by entering areas in or near the wooded localities adjacent to the pond site, disturbing the vegetation, and collecting adults as they attempted to bite. Aedes, as well as a few deer flies (Chrysops ssp.), were collected along the margins of the woods adjacent to the stabilization pond site. Adult biting insects were captured with an aspirator and identified either with the use of a hand lens that had a magnification power of 14 or returned to the laboratory where dissecting microscopes were available.

Entomology studies of this type usually begin early in the spring of the year and continue until the first hard freeze occurs. In Michigan, this period usually is from early May through mid-October. Entomological observations for the project were made on an approximately bi-weekly schedule in 1972 and 1973, and weekly in 1974. Actual observation beginning and ending dates for this three-year period were: April 18 and October 8 for 1972, May 10 and November 8 for 1973, and June 24 and October 10 for 1974. Observations in 1974 were started somewhat later than usual because the spray operations were not maintained on a continuing basis until the first week of July.

RESULTS AND DISCUSSION

The general results of the entomological study and a brief discussion of these results are presented chronologically by year. Specific areas considered are the ponds, the ditches adjacent to the ponds, and the summer irrigation site (Figure 12). There was no indication of any type of insect production in the winter spray irrigation site.

1972 Considerations

Water levels in each of the five stabilization pond cells remained rather high during most of the study period, providing excellent harborages for immature mosquitoes around the pond margins where the growth of emergent vegetation became lush and dense as the summer progressed. The first immature mosquitoes to appear were early instar Culex, found in very large numbers in the connecting pipe well between cells 3 and 4 on June 9 (Figure 13). Since Culex females overwinter in the adult stage, it is possible that these larvae hatched from egg rafts produced by such overwintering adults and represented the first generation of the year. Large numbers of Culex pipiens were still present in this connecting well on June 30 but were not found in this or other connector wells after that date - probably because the frequent and often heavy rains during July and August produced a rather strong current in the connecting pipes that made them unsuitable as mosquito larval habitats. From this initial site, Culex infestations had spread to each of the cells by June 30. Anopheles larvae were the first collected in cells 3, 4 and 5 on July 25 and remained, with one exception, in these sites in increasing numbers throughout the rest of the report period.

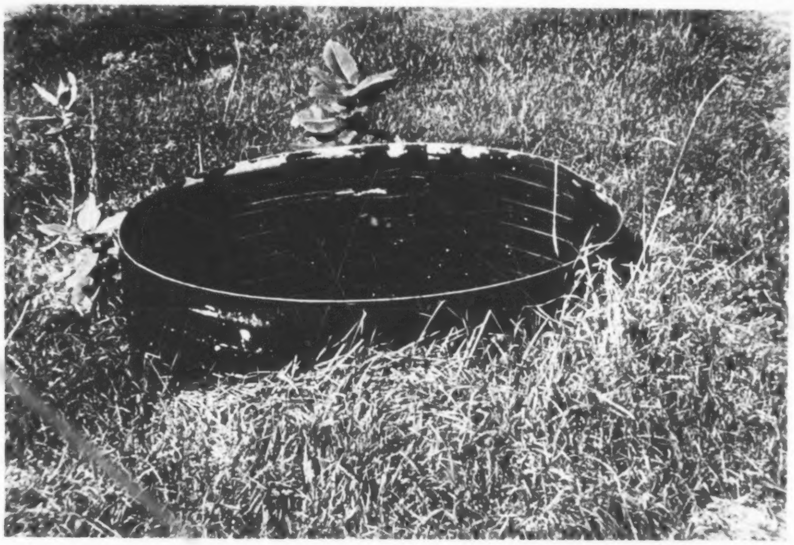

Figure 13. Drop-manhole leading to gravity overflow connectors between stabilization ponds are breeding sites for large numbers of insect pests.

No species of man or animal biting insects other than mosquitoes was found in, or in the immediate vicinity of, any of the treatment cells. Between May 9 and 18, however, there was a massive emergence of a non-biting midge, Tendipes tentans. After this emergence, the water surfaces of cells 3, 4 and 5 contained masses of cast pupal skins that were up to 51 or 76 mm in depth at some locations around the shoreline.

The seepage ditch and the small stream bordering the stabilization pond area (ditches 3 and 4, respectively) were sampled repeatedly, but no insect species pertinent to this study were found. Ditch 3 remained covered with a thick surface mat of aquatic vegetation throughout most of the study period and was virtually devoid of insect life. Ditch 4 on the northeast side of the pond area contained extensive emergent vegetation - both aquatic and semi-aquatic - but the conditions there were unfavorable for the development of mosquitoes or other types of biting insects. A variety of aquatic Hemiptera and Coleoptera were present in varying numbers throughout the study period.

During the early part of the summer, there were large numbers of biting Aedes stimulans in the vicinity of the study site. These did not originate there, however, but developed in early spring rain and snow-water pools in nearby wooded areas. Adult emergence for this species began about May 16 and was completed within about two weeks. In August and September, some biting Aedes vexans were encountered along the ditch bank near cell 5. These also did not originate within the study site but came from intermittently flooded areas nearby.

No insect problems were noted in the summer irrigation site (Table 24). During this year, however, no irrigation was done because the system had not been completed.

1973 Considerations

Water levels in each of the cells were somewhat lower throughout 1973 than in the previous year. These levels, except on a few occasions, were below the level of the terrestrial vegetation growing on the cell banks. Thus, the extensive larval habitats present in all five cells in 1972 did not materialize in 1973 and, therefore, the mosquito populations in all the cells were markedly lower. The overwhelmingly predominant species present this year, as in 1972, was Culex pipiens. Through the summer, there was a steady increase in the population of predaceous Coleoptera and Hemiptera in cells 2, 3, 4 and 5; a factor which, undoubtedly, contributed to the reduction of the larvae mosquito populations in these cells.

Three ditches in the pond and the summer irrigation areas were sampled. Ditches 3 and 4 produced no mosquito larvae; however, the drainage ditch west of the summer irrigation site (ditch 1) had larvae present.

With the commencement of irrigation in the summer spray site, water accumulations formed in a number of locations; but, with the exception of three, all were relatively transitory and did not provide suitable habitats for larvae mosquito development. One larvae site formed in the shallow ditch between the road and the check area at the extreme southeast corner of the 102 mm irrigation area. Some water was present in the site at all times and the vegetation growing adjacent to the permanent water accumulation was subject to periodic flooding when the 102 mm per week area was sprayed. These conditions provided an excellent habitat for mosquitoes and a variety of other aquatic insects throughout the summer and early fall. The second site extended from the northernmost border of the sod plot in the 102 mm area to the southern boundary of the sod plot in the 76 mm spray area. This low area was roughly rectangular and extended through plots containing Rose-of-Sharon, Radiant Crabapple, Redbud Crabapple, White Spruce, and Dark Green Arbovitae plantings. The third larvae collection site was located near the east end of the 76 mm spray area in the ladino clover plot.

TABLE 24. RESUMÉ OF LARVAL MOSQUITO HABITATS AT BELDING, MICHIGAN WASTEWATER IRRIGATION PROJECT 1972-1974

Species	*1972	1973		1974	
	Ponds	Ponds	Spray Areas **	Ponds	Spray Areas
Aedes triseriatus	-	-	+	-	-
Aedes vexans	-	-	+	-	+
Anopheles punctipennis	-	+	+	+	+
Anopheles quadrimaculatus	+	-	+	+	+
Coquillettidia perturbans	-	-	+	-	-
Culex erraticus	-	-	+	-	-
Culex pipiens	+	+	+	+	+
Culex restuans	-	-	-	+	+
Culex salinarius	-	-	-	+	+
Culex tarsalis	-	-	+	-	-
Culex territans	+	-	+	+	+
Culiseta inornata	-	-	+	+	+
Culiseta impatiens	-	-	+	-	-
Culiseta melanura	-	-	+	-	-

*Irrigation site not yet in operation.

** A + sign indicates the presence of local mosquito habitats.

While it was anticipated that some mosquito breeding would occur in the summer irrigation site, the numbers and diversity of the species collected there were remarkable. The Culex pipiens present in the oxidation cells throughout the summer apparently extended into the spray site as did Anopheles punctipennis later in the summer. This is not expected in view of the proximity of the ponds and the irrigation site. The presence of eight additional species is quite unusual and has significance of some magnitude. Four of the ten mosquito species that became established in the summer spray site are not likely to be of real significance as biting human pests, however great their numbers may become. These feed only on cold blooded vertebrates, birds and large domestic mammals. The other six species feed on humans and could become bothersome as the flight range of several of these species is adequate for them to move from the summer irrigation site into Belding and back.

The deefly (Chrysops spp.) population in the area appeared to be higher in 1973 than in the previous year, but this was independent of the spray operation since the adults would have developed from eggs deposited in 1972 before spray operations were started.

1974 Considerations

Unlike 1973, the water level fluctuations in all oxidation cells, except cell 5, were sufficient to periodically flood the peripheral marginal vegetation and provide suitable sites for the production of mosquito larvae. Additional mosquito breeding sites were produced when this vegetation was mowed and allowed to fall back into the water, creating isolated shoreline water pockets that were protected from wave action and predaceous aquatic insects and fish. Mosquito species diversity in the pond cells in 1974 was much greater than in previous years and the species that utilized these breeding sites were, with one exception, the same as those breeding in the spray irrigation site (Table 24). This important finding will be discussed under the next section - Mosquito Data Summary.

Shortly after the spray irrigation was started early in July, water accumulations began to appear in a number of low areas in the spray site. By the third week of the spray operation, the soil in these locations had become saturated and these areas remained flooded for the rest of the summer. Thirteen of the water accumulations in the spray site and an adjacent drainage ditch were selected as larval collecting sites and sampled weekly. As the summer progressed, these water deposits continued to increase in size as additional water accumulated in the depressions. It is suggested that the apparent reduction in the number of larvae in these locations in August, as determined by the number present in three dips per week made at each collection site, actually reflected a reduction in the density of the larval populations rather than in the total numbers present in the progressively larger accumulations of water. The frequent use of a tractor mower during the early part of the spray season produced deep water-filled ruts which later became filled with vegetation and served as mosquito breeding sites as well as enhancing the spread of the accumulated water.

Two tabanid species present in the area, Chrysops, callida and C. frigida, actively fed on humans; but it is not known at this time whether or not these two species breed and develop within the project boundaries. Other tabanid species also were observed but did not attempt to bite humans.

Mosquito Data Summary

Entomological studies conducted at the Belding spray irrigation project during the 1972-74 seasons have shown that marked changes have occured in the mosquito fauna there as a result of the spray operations (Table 24). In 1972, prior to the start of spraying, mosquito breeding was confined to the stabilization cells and consisted almost exclusively of one species, *Culex pipiens*, which is not normally a pest of humans in the north central part of the United States. Two other species occurred sporadically and in very limited numbers of the cells. Of these, *Culex territans* is not known to feed on humans while *Anopheles quadrimaculatus*, although it will bite humans, occurred in such small numbers that it was of no significant concern. In 1973, *Culex pipiens* was present in the oxidation ponds in very high numbers. The only other species using that habitat, *Anopheles punctipennis*, will feed on humans, but was collected only once and then in very limited numbers.

The start of spray irrigation in 1973, however, caused an increase in both the numbers and the diversity of the mosquito species that began to use the project site for a breeding habitat. In that year, while only two species were collected from the oxidation ponds, no less than 12 had moved into the three areas of water accumulation that formed as a result of the spray operation. Finding this many species in close association in such a limited area is quite unusual. At the end of the 1973 season, however, it was not known whether or not the proliferation of species was an indication of future developments or merely a transitory phenomenon.

Irrigation during the 1974 season produced many more semi-permanent water collections in the irrigation site than in the previous year and it now seemed apparent that most of the species that were newly arrived in 1973 had become established in the project site. Further, mosquito production in the spray site during 1974 was numerically much greater - both in larval density and total numbers present - than in 1973. Of perhaps equal or greater significance was that all but one of the species breeding in the spray area during 1974 also began utilizing the oxidation ponds as breeding sites so that, where formerly only two or three species had been present, there now were seven species. Their expansion into the cells gave them a much greater potential for population increases than if they had confined their larval breeding locations to the spray site alone. The biological plasticity of mosquitoes which enables them to adapt quickly and efficiently to changing environmental conditions is most evident at Belding in our finding *Culex territans* present in every cell, from cell 1 with its extreme degree of organic pollution to the relatively clear, clean water of cells 4 and 5. Larvae of this species rarely occur in polluted water but did, when given the opportunity, utilize the highly polluted water of cell 1. The remaining species now present in the project area, as well as others that later may be introduced there, can be expected to have similar cosmopolitan tastes in their selection of breeding sites, although perhaps not to the same degree as *C. territans*.

The critical point that should be emphasized is that the operation of a spray irrigation project in close proximity to the existing oxidation ponds has produced a variety of new ecological niches and that these niches now are occupied by a number of mosquito species that formerly were not present or were present in such small numbers that they were of no practical significance. The establishment of new species in the area after the spray operation began in 1973 and the expansion and amplification of the larval breeding sites utilized by them in 1974 indicate that the project, and others similar to it, have the potential for producing large populations of an impressive variety of mosquito species. Several of the species breeding in the project area during 1973 and 1974 are known to be capable of transmitting human and animal diseases that are present in Michigan (Table 25).

As of the end of the 1974 season, it did not appear that the mosquito species associated with the project site had stabilized or that the observations made in the past year can be considered to be typical of what may occur in future years. Observations must be made over a longer period to determine whether natural predators and other limiting factors in the area will effectively repress the mosquito population without the employment of specific, directed mosquito control measures. Note that in 1973, 12 species were found in the spray areas; while in 1974, only eight of these remained. It is certain, however, that the disposal of sewage oxidation pond effluent by spray irrigation can create a diversity of excellent mosquito breeding habitats that are suitable for use by a number of species.

In 1975, field observations on biting insect populations were started during the fourth week of May, a few days after the appearance of the first adult mosquitoes in this part of Michigan. Entomological observations were made on an approximately weekly schedule throughout the summer and terminated with the occurrence of the first hard freeze. Though the data have been secured, they have not been analyzed due to administrative difficulties in securing an appropriate agreement for the continuation of the studies during the grant extension period.

Entomological studies of the Belding spray irrigation site were not continued sufficiently long to determine whether or not the observed changes in the diversity and populations of mosquitoes would become stabilized. This is an essential factor in determining if this project and others similar to it should be required to incorporate some type of mosquito surveillance/control activity as part of their standard operations. As a reasonable precaution, however, all spray irrigation projects should be located, designed and operated so as to preclude, to the maximum degree possible, the surface accumulation of sprayed effluent and thus eliminate or greatly reduce the potential for mosquito production.

TABLE 25. POTENTIAL MOSQUITO-DISEASE RELATIONSHIPS

Mosquito species[a]	Eastern equine encephalitis (EEE)	Western equine encephalitis (WEE)	California encephalitis (group)	Dog heartworm *Dirofilaria immitis*
Culex pipiens	--	possible vector[b]	possible vector	possible vector[c]
Culex tarsalis	--	proven vector[d]	possible vector	possible vector
Culex territans	possible vector	--	--	possible vector
Aedes triseriatus	possible vector	--	proven vector	possible vector
Aedes vexans	possible vector	possible vector	possible vector	possible vector
Anopheles quadrimaculatus	--	--	--	proven vector
Anopheles punctipennis	--	--	possible vector	possible vector
Culiseta inornata	--	possible vector	possible vector	--
Culiseta melanura	proven vector-esp natural enzootic cycle	possible vector	possible vector	--
Coquilletidia perturbans	possible vector	--	possible vector	possible vector

[a] The three other mosquito species present, *Culiseta impatiens*, *Culex restuans* and *Culex salinarius* have never been incriminated as vectors or possible vectors of these four diseases.

[b] For the three types of encephalitis listed, a possible vector is one which has been found to be infected with the virus in nature, or has been shown to be capable of transmitting it in the laboratory.

[c] A possible vector for dog heartworm is one in which filariae are known to develop to the infective stage.

[d] A proven vector is one for which both epidemiological evidence and controlled laboratory studies have shown conclusively that it is a vector in nature.

SECTION 9

WINTER SITE STUDIES

The natural soils of the winter irrigation site are mostly Gladwin and Glendora. These soils are moderately to poorly drained and frequently have a high water table. In the excavation of the ponds, however, the entire winter irrigation site was covered from 0.6 to 1.3 m deep with sandy loam soil. This filling, plus the construction of ditch 3 on the western side of the site (Figure 10), was expected to keep the water table sufficiently low for wastewater additions during winter. Final grading left the site nearly level from north to south, but with slight grades both to the west toward ditch 3 and to the east toward the Flat River. With the soil elevation 1.8 to 2.4 m higher than water levels both in the ditch and in the river and with sandy fill material, no subsurface drainage problems were expected.

The winter irrigation system is a solid-set, buried-pipe arrangement as shown in Figure 14. These sprinklers are placed on a 12 by 12 m staggered pattern. Thus, the laterals are placed 12 m apart and the sprinklers are spaced 12 m apart along the laterals in a triangular manner to get good uniformity of wastewater coverage of the area. The laterals are 51 mm PVC pipe laid on grade for rapid draining back to the control manhole after a winter run. Valves are manually controlled to supply the application level desired. The sprinklers are comprised of three types: Rain Bird 30 WS, Buckner 8601 GE, and stationary-deflectors as developed at Penn State. Equal numbers of each type are being used to compare their differences in operation during freezing conditions. Each type is designed to emit 0.27 l/s at 380 millipascals (mPa) for a precipitation rate of 6.35 mm per hour.

The winter and the summer system each was designed for 9.5 l/s total flow at a head of 53 m. This gives the flexibility of using either pump for either system and the possibility of using both pumps for irrigating summer and winter areas simultaneously. Twenty-four 0.4 l/s sprinklers in the summer site or thirty-six 0.27 l/s sprinklers in the winter site can be activated by either pump. Typical stationary-deflector winter performance is seen in Figure 15.

In the original project outline, irrigation of the winter site was primarily to demonstrate that wastewater could be distributed during winter months of sub-freezing temperatures. As a side benefit, it was hoped to learn about factors related to cold weather operation, such as functioning of various types and makes of sprinkler heads, the hydrologic problems involved, and the effects on the crops irrigated. Original design application levels were to be 51 and 102 mm per week; however, these were later changed to an application level of 51 mm per week with one half the amount applied twice

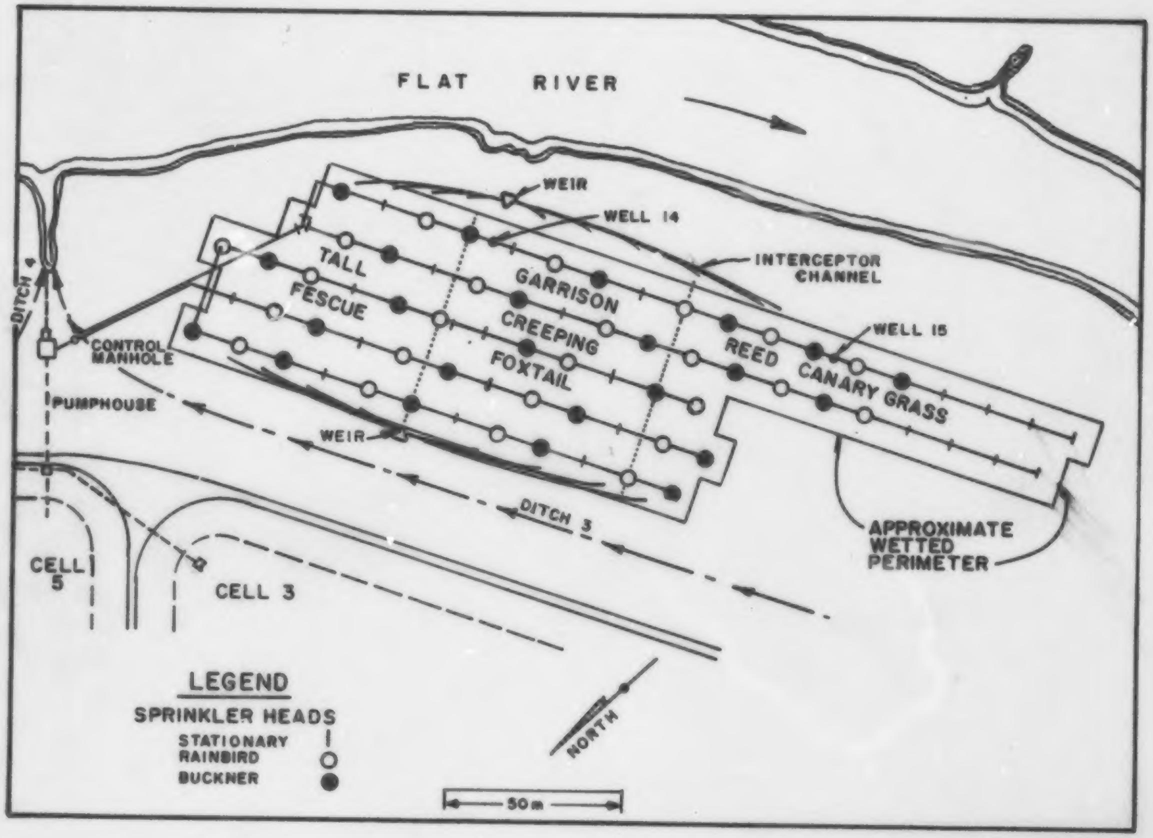
FLAT RIVER
WEIR
WELL 14
INTERCEPTOR CHANNEL
WELL 15
TALL FESCUE
GARRISON CREEPING FOXTAIL
REED CANARY GRASS
DITCH 4
CONTROL MANHOLE
PUMPHOUSE
WEIR
DITCH 3
APPROXIMATE WETTED PERIMETER
CELL 5
CELL 3
LEGEND
SPRINKLER HEADS
STATIONARY
RAINBIRD
BUCKNER
NORTH
50 m

Figure 14. Winter site showing irrigation system, vegetative cover types, monitoring wells, and surface ditches.

each week. Tall fescue, creeping foxtail, and reed canary grasses were established on the winter site (Figure 14). Though the reed canary and creeping foxtail grasses were somewhat slow in starting, all three were fairly well established by the end of the 1974 growing season.

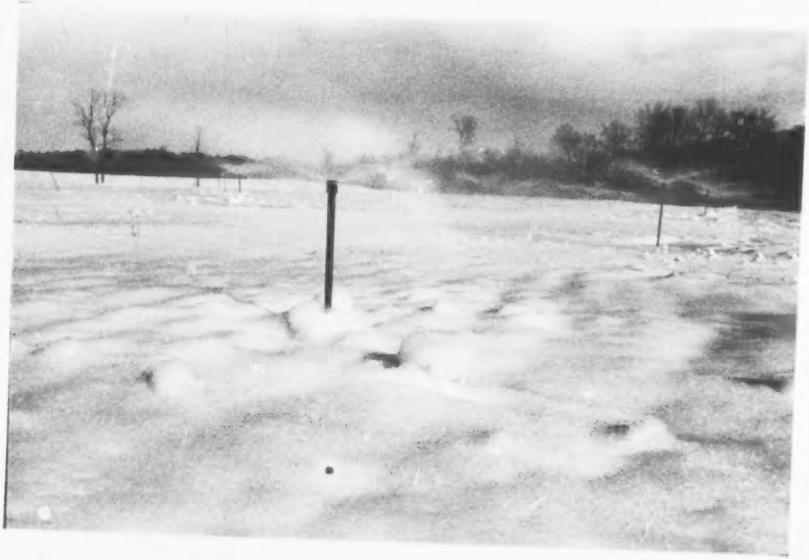

Figure 15. Winter irrigation site and stationary-head sprinkler.

The first three winter irrigation seasons were from November 29, 1972, through March 5, 1973; from January 3, 1974, through February 25, 1974; and from December 9, 1974, through March 20, 1975. The rates and amounts irrigated and the data collected during each of these winter seasons varied extensively. One major problem of winter irrigation encountered was the plugging of irrigation nozzles with dead minnows. During the fall discharge period, minnows were carried out of the ponds, passed through the chlorine contact chamber, and moved into the irrigation wet well; from here they were pumped into the irrigation lines. A second problem was runoff into the Flat River. The first problem was solved by a change of managing water flows prior to winter irrigation. The second problem required additional study.

In the two-year extension of the project, it was decided to secure more definitive data on the hydrologic regime of the winter system. The irrigation system was checked for proper sprinkler heads and appropriate nozzle sizes; valves controlling flow to specific areas and those permitting drainage of the irrigation system were made functional and accessible; and pump pressures and discharge rates were checked so that the desired application levels could be assured. The site was prepared for collecting more specific hydrological data. Interception channels were constructed both on the eastern and western sides of the field. These channels (Figure 14) were outletted through stilling basins and over V-notch weirs so that overland flow rates could be determined.

The addition of the interceptor channels and weirs, plus the existing well sites 14 and 15, provided reasonable monitoring of both the rate and quality of water moving from the site. The quantity applied to the site was determined by a water meter and by the pressure at the sprinkler heads in conjunction with the nozzle size, while the quality applied was that of cell 5 of the pond system.

High runoff rates observed at the Belding site during previous winters were not compatible with the low ones observed at the Penn State project over a ten-year period on somewhat similar soils. Thus, it was decided a pre-winter test should be run to help define the existing hydrologic conditions of the site.

This test was run during the period October 14-17, 1975. The weather was fair, the grass was 15 cm tall, and the newly constructed interceptor channels of sandy and gravelly soil looked as though water would go through the channel bottoms like a sieve. The entire winter site was irrigated at the rate of 6.35 mm per hour from 10 a.m., October 14, through 2 p.m., October 16 (52 hours). Depths to water and chloride content in the on-site wells throughout the test are listed in Table 26, while rates of runoff from the site are presented in Table 27.

The maximum total increase of water level for any of the wells during irrigation was 0.12 m. This small level increase, as well as the very small changes in chloride content, indicates that little of the 33 cm of applied wastewater passed the well screens. The maximum, and nearly steady, 5.4 l/s rate of runoff was one third of the 17.3 l/s rate of application to the site.

These results indicate that the soil has very low infiltration, percolation, and transmissibility rates. Approximate percentages in the "plow layer" of gravel are 15 to 25, of sand are 70 to 80, of silt are 2 to 5, and of clay are 1 to 2. Frequently, soils this coarse have high rates of water movement through them. Two factors seem to account for these slow water movement rates: (1) the soil particles are non-uniform in size permitting high density when worked; and (2) in placing the soil on location, it was extensively worked and compacted by the transporting equipment.

Belding's winter irrigation schedule for 1975-76 began on November 13 and concluded on March 25. Fifty millimeters per week were applied, 25 mm each on Monday and on Thursday. On each day, half the site nearest the stream (east side) was irrigated the first 4 hours at 6.35 mm per hour, then the half nearest the pond (west side) was irrigated the next 4 hours at the same rate. Winter irrigation and site runoff water quality data were secured almost weekly, while well water quality and depth to ground water data were taken approximately every three weeks. The depth of runoff flow over each weir was secured at the beginning of irrigation, after 4 hours, and when irrigation terminated each day.

Runoff phosphorus concentrations (Table 28) ranged from 43 to 75 percent of the concentrations applied. Much of the reduction in concentration was due to dilution as liquid amounts of precipitation ranged from 7.6 to 12.7 cm per month, whereas irrigation amounts were only about 20.3 cm per month. Some

TABLE 26. DEPTHS TO WATER AND CHLORIDE CONTENT IN WELLS DURING HYDROLOGIC PRE-TEST OF WINTER SITE*

Date		Well 14N		Well 14S		Well 15	
Day	Time	Depth (m)	Cl⁻ (mg/l)	Depth (m)	Cl⁻ (mg/l)	Depth (m)	Cl⁻ (mg/l)
14	10 a.m.	1.71	8	1.73	9	0.81	12
15	10 a.m.	1.73	7	1.69	9	0.78	14
16	1 p.m.	1.64	7	1.65	8	0.69	15
17	8 a.m.	1.63	7	1.65	8	0.75	15

*Irrigation began 10 a.m. October 14 and ended 2 p.m. October 16, 1975.

TABLE 27. DEPTHS OF WATER AND RUNOFF RATES OVER V-NOTCH WEIR DURING HYDROLOGIC PRE-TEST OF WINTER SITE*

Date		West Side V-Notch		East Side V-Notch	
Day	Time	Depth (cm)	Flow (l/s)	Depth (cm)	Flow (l/s)
14	11 a.m.	0.0	0.0	0.0	0.0
15	11 a.m.	5.1	0.76	10.16	4.42
15	3 p.m.	5.1	0.76	10.16	4.42
16	8 a.m.	5.7	1.01	10.16	4.42
16	2 p.m.	5.7	1.01	9.53	3.79
17	8 a.m.	0.0	0.0	0.0	0.0

*Irrigation began 10 a.m. October 14 and ended 2 p.m. October 16, 1975.

TABLE 28. 1975-76 WINTER IRRIGATION AND SITE RUNOFF WATER QUALITY (mg/l except pH)

Date	Cl	BOD	SS	O-P	T-P	NO_3	NH_3	TKN	pH	DO
11/20/75	115	2.0	3	3.2	3.2	0.69	5.2	5.5	8.0	10.9
Runoff	95	-	-	1.55	1.65	0.32	0.8	2.0	8.2	-
12/11/75	110	1.6	1	2.25	2.4	1.01	6.6	8.45	7.6	10.0
Runoff	100	-	-	0.98	1.02	0.4	0.72	2.25	8.0	-
12/18/75	110	2.2	2.5	2.6	2.65	0.88	5.75	8.65	7.8	12.9
Runoff	160	-	-	-	1.98	1.0	5.0	7.45	8.0	-
1/29/76	120	2.6	3.0	4.4	4.65	0.21	7.95	13.5	7.7	9.2
Runoff	135	-	-	2.4	2.4	0.21	2.25	5.9	7.9	-
2/5/76	125	1.1	3.5	4.8	4.9	0.25	8.5	11.8	7.6	8.4
Runoff	160	-	-	3.25	3.3	0.21	3.4	7.0	7.9	-
2/12/76	135	6.2	7.5	5.2	5.4	0.21	12.3	12.5	7.6	7.5
Runoff	125	-	-	2.5	2.6	0.32	2.9	3.5	7.9	-
2/26/76	130	3.6	14	5.95	7.8	0.21	12.3	14.3	7.4	6.2
Runoff	75	-	-	3.0	3.75	0.12	3.0	6.4	7.7	-
3/4/76	6.7	7.5	5.3	6.15	-	10.8	16.9	-	7.0	-
Runoff	60	-	-	2.6	2.9	0.13	2.0	7.65	7.6	-
3/11/76	-	12.9	19.5	4.9	5.5	0.13	11.0	15.5	7.6	8.8
Runoff	-	-	-	3.35	3.65	0.18	4.4	7.4	7.9	-
3/18/76	120	11.2	21	4.8	5.9	0.23	11.8	19.4	7.9	11.2
Runoff	115	-	-	3.2	3.2	0.20	8.2	14.3	8.0	-
3/25/76	120	20.9	27	4.1	4.5	0.27	8.8	13.9	8.1	11.9
Runoff	135	-	-	2.5	2.6	0.21	1.4	4.4	7.8	-

reduction in phosphorus levels also probably occurred due to interflow. Runoff chloride concentrations ranged from 46 to 115 percent of the concentrations applied. The reduction of chloride levels was due primarily to dilution from precipitation, whereas the increases of chloride levels was due primarily to the freezing-out of relatively pure water producing a higher concentration in the remaining liquid.

The ground water chloride concentrations (Table 29) showed very little irrigated water reached wells 14N and 14S. Even though more irrigated wastewater reached well 15, as indicated by the chloride concentrations, the phosphorus concentrations indicated almost complete removal of phosphorus by the soil.

Depths to the ground water (Table 30) indicate very little water level increase from October through February 10. During this time period, some of the irrigated water ran off or froze and remained on the surface of the site. From February 10 through March 30, the increased height of ground water indictated water from the melting ice and snow percolated to the water table faster than deep percolation or lateral transmissibility could transmit it from the area. Runoff depths over V-notches at the winter site (Table 31) from January 2 through February 9 indicated much of the irrigated water froze and remained on the surface of the site, and from February 9 through March 25 indicated this frozen water, plus snow, melted and ran off the site.

The winter ground water levels and runoff depth data imply very slow water movement rates into and through the soil, and verify the data secured during the October pre-winter test. The winter site soils remained open (soil did not freeze) throughout the winter, probably due to a good depth of snow cover. This open soil condition was verified by shovelling through the snow and into the soil in January and also by the ground water level increase in the last half of February and in March.

The original objective, to demonstrate that wastewater can be distributed in winter, has been fulfilled. Commercial sprinklers, as used on the winter site, do have the problem that not all of them continue to rotate when temperatures fall below freezing. Ice forms on the spring and on the kicker until the rotating action is stopped; however, the water continues to run through the nozzle. The specially fabricated stationary-deflector sprinklers continue to spray in winter but do not produce as large or as uniform a distribution pattern as desired. Sprinklers of all types became plugged with foreign matter, but this is merely a problem of management or of maintenance. The high runoff rates seemed to occur more due to low water movement rates through compacted soil than to frozen soil. Winter irrigation did not detrimentally affect any of the three types of grass growing on the winter site.

TABLE 29. CHLORIDE AND TOTAL PHOSPHORUS CONCENTRATIONS FOR WINTER SITE WELLS DURING 1975-76 WINTER IRRIGATION SEASON (mg/l)

Date	Chloride			Total Phosphorus		
	Well 14N	Well 14S	Well 15	Well 14N	Well 14S	Well 15
Oct. 27, 1975	6	8	17	0.025	0.015	0.015
Nov. 24, 1975	-	-	-	0.025	0.020	0.025
Dec. 16, 1975	6	8	34	0.025	0.025	0.025
Jan. 14, 1976	7	9	46	0.020	0.020	0.015
Feb. 10, 1976	7	11	80	0.055	0.055	0.055
Mar. 9, 1976	7	11	55	0.015	0.020	0.020
Mar. 30, 1976	8	11	60	0.015	0.010	0.015

TABLE 30. DEPTHS TO WATER TABLE FROM GROUND SURFACE AT WINTER SITE DURING 1975-76
(m)

Date	Well 14N	Well 14S	Well 15
Oct. 27, 1975	1.58	1.60	-
Nov. 24, 1975	1.62	1.63	0.74
Dec. 16, 1975	1.26	1.27	0.48
Jan. 14, 1976	1.53	1.55	0.62
Feb. 10, 1976	1.56	1.57	0.62
Mar. 9, 1976	0.68	0.69	0.03
Mar. 30, 1976	1.13	1.14	0.30

TABLE 31. WINTER IRRIGATION SITE RUNOFF DEPTHS OVER V-NOTCHES

Date	Hours after irrigation began		Hours after irrigation ended		Weir overflow (cm)	
	EAST	WEST	EAST	WEST	EAST	WEST
11/13/75	4	0	0	-	10.16	0
	8	4	4	0	5.84	0
11/20/75	4	0	0	-	0	0
	8	4	4	0	7.47	4.11
11/24/75	4	0	0	-	9.19	0
	8	4	4	0	6.65	4.46
12/01/75	4.5	0	0	-	8.26	0
	8	4	4	0	5.72	0
12/08/75	4	0	0	-	8.13	0
	8	4	4	0	6.99	6.35
12/11/75	4	0	0	-	10.46	0
	8	4	4	0	7.62	3.81
12/15/75	4.5	0	0	-	10.80	0
	8	4	3.5	0	9.19	4.78
12/22/75	5	1	0	-	6.35	0
	8	3	3	0	3.81	0
1/02/76	4	0	0	-	5.08	0
	8	4	4	0	8.26	0
1/06/76	4.5	0	0	-	6.99	0
	8	3.5	3.5	0	4.46	0
1/08/76	4	0	0	-	8.89	0
	8	4	4	0	6.35	0
1/12/76	4.5	0	0	-	6.99	0
	8	3.5	3.5	0	6.35	0
1/15/76	4.5	0	-	-	5.72	0
	8.25	3.75	3.75	0	4.46	0
1/19/76	4.25	0	0	-	4.78	0
	8.25	4	4	0	2.84	0
1/22/76	4	0	0	-	5.72	0
	8	4	4	0	4.11	0
1/26/76	4.75	0	0	-	5.72	0
	8.	3.25	3.25	0	4.46	0
1/29/76	4.25	0	0	-	5.72	0
	8.25	4	4	0	3.81	0

(continued)

TABLE 31. (CONTINUED)

Date	Hours after irrigation began		Hours after irrigation ended		Weir overflow (cm)	
	EAST	WEST	EAST	WEST	EAST	WEST
2/02/76	4.5	0	0	-	2.84	0
	8.25	3.75	3.75	0	2.84	0
2/05/76	4.25	0	0	-	3.18	0
	8.25	4	4	0	3.18	0
2/09/76	4.75	0	0	-	0	0
	8.25	3.5	3.5	0	3.81	0
2/12/76	4.25	0	0	-	6.35	0
	8.25	4	4	0	7.92	3.18
2/16/76	4	0	0	-	10.80	0
	8	4	4	0	10.16	6.35
2/23/76	4.25	0	0	-	6.99	0
	8.25	4	4	0	5.72	1.91
2/26/76	4	0	0	-	12.70	0
	8	4	4	0	12.07	5.72
3/01/76	4	0	0	-	10.16	0
	8	4	4	0	4.78	3.18
3/04/76	4.5	0	0	-	13.34	1.57
	7.5	3	3	0	13.97	7.62
3/08/76	4	0	0	-	10.16	-
	8	4	4	0	8.59	-
3/11/76	4	0	0	-	11.43	0
	8	4	4	0	8.26	6.35
3/15/76	4	0	0	-	11.43	0
	8	4	4	0	8.26	5.38
3/18/76	4	0	0	-	10.46	0
	7.5	3.5	3.5	0	7.92	5.08
3/22/76	4	0	0	-	11.43	0
	8	4	4	0	8.59	4.78
3/25/76	4	0	0	-	9.86	0
	8	4	4	0	6.99	3.02

SECTION 10

REFERENCES

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2. Williams, T. C. Utilization of Spray Irrigation for Wastewater Disposal in Small Residential Developments. In Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland. The Pennsylvania State University Press. University Park, Pa., 1973. pp. 385-395.

APPENDIX A

TABLE A-1. CERTAIN WASTEWATER CONSTITUENT CONCENTRATIONS IN THE INFLUENT AND IN CELL 5 EFFLUENT DURING SUMMER IRRIGATION SEASONS OF 1975 AND 1976

pH					
	1975			1976	
Date	Influent	Cell 5	Date	Influent	Cell 5
5/21	*	7.8	5/27		8.6
5/30		7.6	6/18		8.4
6/18		9.4	6/30		8.6
7/16		9.0	7/16	7.5	8.0
7/25	7.7	9.1	7/21		7.8
8/01	7.7	9.3	7/30		8.0
8/07	7.4	9.1	8/13		8.3
8/15	7.3	9.0	9/10		8.7
8/20	7.4	9.1	9/22	7.4	8.7
8/28	7.0	8.0	10/06	7.1	8.5
9/10		8.2	10/15		8.0
9/12		8.2			
9/17		8.2			
9/19		8.4			
9/24	7.3	7.9			
9/29		8.1			
10/08	7.7				
Suspended Solids (mg/l)					
6/18		0	5/27		4.5
7/25	72	48	6/18		3
8/01	46	6	6/30		2
8/07	24	1.5	7/17	6	11
8/15	28	8	7/21		22
8/20	25	8	7/30		3
8/28	36	4.5	8/13		6.5
9/10		3.5	9/10		15
9/12		6	9/22	100	10
9/17		5	10/6	117	25
9/19		2.5	10/15		9
9/24	96	6			
9/29		5			
10/08	52				

(continued)

* No entry means no measurement was made.

TABLE A-1 (continued)

Ammonia Nitrogen (mg/l)

	1975			1976	
Date	Influent	Cell 5	Date	Influent	Cell 5
5/21		0.12	5/27		0.08
5/30		0.12	6/18		0.08
6/18		0.12	6/30		0.02
7/16		0.03	7/16	8.68	0.08
7/25	10.3	0.22	7/21		0.22
8/01	20.3	0.08	7/30		0.12
8/07	22	0.23	8/13		0.16
8/15	9.8	0.15	9/10	25	0.08
8/20	16.3	0.1	9/22		0.03
8/28	17.4	0.08	10/6	9.8	0.4
9/10		0.18	10/15		0.18
9/12		0.25			
9/17		0.28			
9/19		0.32			
9/24	16.3	0.18			
9/29		0.18			
10/08	24				

Nitrate Nitrogen (mg/l)

	1975			1976	
Date	Influent	Cell 5	Date	Influent	Cell 5
5/21		0.23	5/27		0.2
5/30		0.21	6/18		0.1
6/18		0.21	6/30		0.13
7/16		0.12	7/16	0.23	0.11
7/25	0.32	0.13	7/21		0.11
8/01	0.18	0.13	7/30		0.2
8/07	0.13	0.13	8/13		0.13
8/15	0.3	0.21	9/10		0.23
8/20	0.13	0.18	9/22	0.18	0.23
8/28	0.13	0.19	10/6	0.43	0.32
9/10		0.13	10/15		0.3
9/12		0.13			
9/17		0.1			
9/19		0.1			
9/24		0.11			
9/29	0.19	0.11			
10/08	0.2				

(continued)

TABLE A-1 (continued)

Total Kjeldahl Nitrogen (mg/l)

	1975			1976	
Date	Influent	Cell 5	Date	Influent	Cell 5
5/21		1.63	5/27		1.83
5/30		1.93	6/18		1.53
6/18		1.93	6/30		1.23
7/16		1.73	7/16	10.5	2.5
7/25	13.2	2.33	7/21		1.7
8/01	24	1.63	7/30		2.0
8/07	26.6	4.35	8/13		2.29
8/15	10.8	1.43	9/10		3.5
8/20	20.3	2.0	9/22	3.88	4.62
8/28	25.5	1.53	10/6	0.43	0.32
9/10		2.24	10/15		3.48
9/12		2.5			
9/17		2.24			
9/19		2.82			
9/24	22.0	1.43			
9/29		1.58			
10/08	25.5				

Orthophosphorus (mg/l)

	1975			1976	
Date	Influent	Cell 5	Date	Influent	Cell 5
5/30		2.6	5/27		1.4
6/18		0.66	6/18		1.15
7/16		0.67	6/30		0.9
7/25	1.86	0.58	7/16	3.0	4.5
8/01	9.9	0.57	7/21		5.2
8/20	12.5	0.52	7/30		4.8
8/28	4.4	0.78	8/13		2.65
9/10		2.4	9/10		1.1
9/12		2.5	9/22	7.3	1.2
9/17		2.7	10/6	1.5	1.35
9/19		2.95	10/15		1.45
9/24	13.4	3.02			
9/29		3.13			
10/08	6.8				

(continued)

TABLE A-1 (continued)

Total Phosphorus (mg/l)

1975			1976		
Date	Influent	Cell 5	Date	Influent	Cell 5
5/21		2.15	5/27		1.55
5/30		2.65	6/18		1.23
6/18		0.72	6/30		1.98
7/16		0.78	7/16	4.4	4.6
7/25	2.75	0.75	7/21		5.6
8/01	8.0	0.63	7/30		5.3
8/15	2.63	0.55	8/13		2.65
8/20	12.5	0.61	9/10		1.65
8/28	4.5	0.78	9/22	11.8	1.45
9/10		2.45	10/6	3.25	1.7
9/12		2.5	10/15		1.95
9/17		2.7			
9/19		2.95			
9/24	15.3	3.2			
9/29		3.18			
10/08	7.25				

BOD (mg/l)

5/21		3.8	5/27		2.2
5/30		1.9	6/13		1.8
6/18		1.8	6/30		1.6
7/16		1.9	7/16	24	5.4
7/25	128	1.8	7/21		5.1
8/01	90	1.6	7/30		2.6
8/07	84	2.2	8/13		3.4
8/15	38	2.2	9/10		12
8/20	52	3.7	9/22	118	15.7
8/28	120	0.7	10/06	44	11.5
9/10		3.1	15/15		14
9/12		3.6			
9/17		3.4			
9/19		3.4			
9/24	110	1.7			
9/29		3.6			
	110				

(continued)

TABLE A-1 (continued)

Chloride (mg/1)

1975			1976		
Date	Influent	Cell 5	Date	Influent	Cell 5
7/16		165	1/02	145	110
7/25	175	160	1/08	130	115
8/20	135	165	1/15	115	120
11/20		115	1/22	110	115
12/11		110	1/29	110	120
		110	2/05	105	125
			2/12	340	135
			2/26	115	130
			3/4	60	130
			3/18	130	120
			3/25	120	120
			6/18		120
			6/30		120
			7/16	140	135
			7/21		130
			7/30		135
			8/13		135
			9/10		135
			9/22	80	
			9/29		135
			10/6	35	135

APPENDIX B

TABLE B-1. METEOROLOGICAL DATA

1971

Day	Month											
	October				November				December			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1					65	29			33	6		
2					50	44	.32		35	6		
3					49	35	0			9		
4					46	30	0.1			8		
5					62	34						
6	60	33	.05						38			
7	58	34	0						38	30		
8					39	14		1.2	40	32	0.05	
9	61	34	.08		44	28		1.0	45	35	0.1	
10					52	29	0	0	60	37	1.6	
11	61	33	0		49	21	0					
12	62	33	0			23	0					
13	55	46	.50			31	0		33	15		
14	60	41	0		61		0		36	18	0.5	
15					59		0		60	33	1.9	
16	73	41	0		55	28	0		37	33		
17					68	44	.07		37	22		
18	62	47	0		63	43	.32			14		3
19	76	45	0		42	37						
20	77	46	0				0.5		34			
21	73	54	0.1						36	28		
22			0.2		29	13		0.5	31	13		
23	63	50	.05		33	9		0.5	44	24		
24					35	23			47			
25	62	48	0		40	24						
26	73	55	0		40	26		1.0				
27	71	41	0			29		1.0	37			
28	71	37	0			28			38	18		
29					33	28		3.0	39	19		
30	74	29	0		29	23		T			0.75	4.5
31												
Total			.98				1.31	8.2			4.9	7.5

TABLE B-2. METEOROLOGICAL DATA
1972

Day	Month											
	January				February				March			
	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow
1					30	20			32	30		TR
2					30	24		2	18	10		1.5
3	32	14		1.5	28	20		1.5	22	0		
4	22	9		1.1	18	5		2				
5	23	5		1.5				3				
6	25	7		0.5					40	3		TR
7	32	20			23	-22			50	40		
8		4			17	-16		6.0	19	4		TR
9	45				21	-10			32	6		
10	46				28	- 7			38	- 4		
11	35	17		1.5	30	-14						
12	43	13										
13	23	20		3					32	27		4
14		5		3	42	26			33	21		1.5
15		-18			38	14			39	28		
16					33	1			36	32		TR
17	35	10			40	20			38	21		
18	42	15										
19	24	19										
20	34	22		6					40	29		
21	36	15			25	10		1.0	55	30		.5
22	43	5			25	20			32	29		TR
23					21	15		1.3	35	14		
24	42	15	0.5		15	20			40	18		
25	11	15		2	37	22		TR				
26	14	0										
27	15	5							45	20		
28	18	4		3	38	20		2.0	43	25		
29		-9		0.5	43	25			37	25		
30				0.5					37	28		4
31	22	6		1.5					32	18		TR
Total			0.5	25.6				18.8				11.5

(continued)

TABLE B-2 (continued)
1972

Day	Month											
	April				May				June			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1					72	44	0.5		73	39	.03	
2					65	52	.035		78	47	.025	
3	40	16		TR	55	43						
4	34	17			64	37						
5	42	24		TR	68	35			79	42		
6	45	25							80	60		
7	22	17		TR			.48		82	41		
8					54	38			82	48		
9					63	35			45	62		
10	62	26			67	29						
11	62	28			76	37				28		
12	63	35			76	39			65	40	.31	
13	54	43	.54						81	50	.20	
14	58	29					.45		87	59		
15					64	49	.38		76	57	2.35	
16			1.5		70	53			68	43	.01	
17	65	45			79	46						
18	76	42			85	47						
19	52	40	.3		85	47			83	46		
20	55	37	.03						77	58	.175	
21	52	34							65	44	0	
22					85	47			64	46	.17	
23					83	47				46	.07	
24	45	29	0.35		89	50				47		
25	60	23			87	52			77			
26	62	23			77	45			74		.035	
27	68	29			83				83	50		
28	67	34							81	52		
29							.22		73	59	.26	
30					54	44	.035		83	60		
31					17	39						
Total			2.72				2.100				3.635	

(continued)

TABLE B-2 (continued)
1972

Day	July				August				September			
	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow
1	83	54			80	58			82		.06	
2	84	60	.05		74	62	0.48		65	51		
3	73	50	.04		70	58			70	38	.005	
4					71	41			70	48		
5	70	41			76	40			74	73		
6	76	39			66	50	0.85		75	51		
7	74	46			63	56	0.11		74	57	0.34	
8	75	51	.08		62	45	0.07		73	63		
9	19	52	.075		69	50			68	37		
10	84	57			72	40	0.01		70	39		
11	72	58				51	0.20		69	42		
12	87	61	.06		82				68	58		
13	76	63	.13		85	54			75	61	0.88	
14	87	59			85	61	0.29		72	52	0.07	
15	79	61	1.47		75	53			78	41		
16	81	52			75	48	0.50		78	50		
17	84	53	0.29		87	52			83	50	0.25	
18	77	64	0.17		88	64	0.78		77	58	1.15	
19	84	63			82	64	0.01		68	54		
20	90	65			83	54			76	49		
21	91	68			86	57			64	53		
22	91	69			88	54	0.38		62	32	.04	
23	86	68	.02		81	63	1.98		60	34	.005	
24	84	61			75	69	.025		70	38		
25	75	52			82	53			68	56		
26	63	45	.38		79	56	.22		70	44		
27	75	52			71	61	.035		67	39		
28	77	51			84	54			68	46	.35	
29	80	47			84	52			65	40		
30	82	49			85	54						
31	82	51	.105		86	53						
Total			2.87				5.94				3.15	

(continued)

TABLE B-2 (continued)

1972

Day	Month											
	October				November				December			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1	65	35			46	31	.315		33	14		2
2	75	36			58	36	.025					
3	73	47			51	38	.02					
4	70	45							25	12		
5	66	49							32	13	0.15	
6	63	48	0.19		55	28	.015		24	12		.5
7	58	29	0.005		52	44	.52		16	-6		
8	61	32			46	42				5		3
9	55	25			41	33			32			
10	60	26			46	32	.03					3
11	65	39	0.01						23	-1		2
12	50	40							33	2	0.5	8
13	52	25			35	26	.045		29	5		
14	59	41	0.025		33	25			30	18		
15	53	22	0.10		36	17				17		3
16	61	23			32	11			30			
17	42	24			32	16				5		
18	36	18	0.03		32	16			36		.03	
19	44	13			35	16		0.25	37	23		
20	48	17			36	21			35	26		
21	42	29	0.57		40	26	.035		36	25		
22	55	33	1.6		34	24						
23	52	42	0.55		36	19						
24	45	30	0.11		36	25						
25	49	22			36	25	.325					
26	56	33			41	25	0.1		33	25		Tr
27	55	28	.13		33	27			35	17		
28	50	42	.18		34	26			33	23		
29	53	35			35	10			38	24	1.5	
30	40	29			40	18		1.5	44		0.5	
31	41	29	.15									0.5
Total			3.65				1.43	1.75			2.68	22.0

TABLE B-3. METEOROLOGICAL DATA

1973

Day	Month											
	January				February				March			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1		8		0.5	45	32	0.1		47	31	0.15	
2	28	23			45	36	0.17		47	35		
3	37	9	0.57								0.15	
4	34	22										
5	20	10			35	26			36	33	0.15	
6					35	29			66	36		
7		0			34	26		3	59	49	0.035	
8	23	4		TR	25	4			46	32		
9	18	11		0.5		1				27		
10	21	11		3		0				33		
11	20	11		0.5	28				67		0.66	
12		4			30	10			44			
13		19			32	7			47	39		
14	33				33	10		4	69	40	0.92	
15	36					18		2	56	54		
16	45	26							41	37		
17	50	39				-25						10
18	54	42	0.3									
19	45		0.2		35				46	21		
20					38	32		1	41	21		
21	43	17			30	27		2	46	19		
22	40	32	0.3		24	11		2	44	20		
23	35	30			34	17		1		20		
24	38	22								24		
25	48	24						4	55			
26	56	24			27	3			55			
27					32	0			55	25		
28					44	4			52	25	0.16	
29	29	11							51	38	0.79	
30	34	13							55	44	0.005	
31	33	19							44	34		
Total			1.37	1.8			0.27	19			3.02	10

(continued)

TABLE B-3 (continued)
1973

Day	Month											
	April				May				June			
	T	T	Precipitation		T	T	Precipitation		T	T	Precipitation	
	Max	Min	Rain	Snow	Max	Min	Rain	Snow	Max	Min	Rain	Snow
1	57	37	0.01		70	45	1.48		78	46	.09	
2	48	53			67	58	.11		80	56	.015	
3	46	39	0.13		41	36	.08		76	60	1.01	
4	42	36	0.04		55	33			79	61	.18	
5	43	31			63	28			77	62	.19	
6	55	43	0.01		66	36			76	62		
7	53	41			67	43	.81		77	55		
8	43	32			65	54	.095		83	58		
9	35	27		4	72	49			83	62		
10	34	26		4	67	49	.015		86	53		
11	40	12			63	42			87	69		
12	45	19			57	44	.01		87	66	.03	
13	46	25			55	38	.005		80	42		
14	56	21			56	32			82	48		
15	68	24			60	28			84	53		
16	58	35	0.15		55	46	.04		82	61	1.34	
17	63	30			53	29			71	57	0.12	
18	70	49	0.12		65	28			80	60	.005	
19	71	51			65	48	.085		80	62		
20	78	55			72	36	.005		79	58	.005	
21	74	60	0.52		73	39			79	56		
22	64	59	0.89		61	48			65	53		
23	64	40			64	53	.26		75	52	.19	
24	57	33			72	39			77	53	.01	
25	60	33			66	51			80	50		
26	62	32			66	43	.42		85	66	.005	
27	57	43			61	50	.01		82	64	.06	
28	55	34			69	49	.96		66	57	.66	
29	47	27	0.32		57	52	.32		65	56	.285	
30	60	34	0.25		55	47	.13		72	56	.01	
31					73	37	.09					
Total			2.44	8.0			4.925				4.205	

(continued)

TABLE B-3 (continued)
1973

Day	July				August				September			
	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow
1	81	57			78	61	0.005					
2	85	58	.315		74	61	.294					
3	73	62	.055		82	52			91	64		
4	77	55				50			86	69	.02	
5	79	57			86				82	65		
6	87	53			84	68			74	50		
7	86	59			86	68				47		
8	86	68			88	68	0.73					
9	87	64	0.22		83	69	.08		75		.03	
10	82	63			80	63	.25		77	41		
11	72	51			82				74	56		
12	85	49	0.19		80	55			73	39		
13	88	65	0.037		82	51			74	43		
14	78	58			80	57			76	53		
15	79	51			81	53						
16	77	48			82	51						
17	82	48			82	52			45	37	1.3	
18	82	61				54	.03		65	34		
19	85	59					.31		64	38	0.1	
20	71	68	0.25		77				58	40		
21	79	63			72	50			58	34	.04	
22	82	60			72	44			72		.08	
23	85	56			64	56	0.065				.05	
24	84	60	0.02		76	55			70	41		
25	88	64				53			80	54	.47	
26	82	67	.484		92				83	63		
27	81	64			93	72			78	67		
28	68	60	0.04		93	68			69	59	.095	
29	81	49			92	66					.02	
30	80	61	.18		83	67	.35					
31	80	64	1.30		88	66						
Total			3.091				2.114				2.205	

(continued)

TABLE B-3 (continued)

1973

	Month											
	October				November				December			
	T	T	Precipitation		T	T	Precipitation		T	T	Precipitation	
Day	Max	Min	Rain	Snow	Max	Min	Rain	Snow	Max	Min	Rain	Snow
1	73	46			49	40	.015			24		
2	66	61	.06		47	38	.22					
3	69	59							56			
4	66	57	.01						54	38	0.56	
5		38			31	21			40	32	.05	0.5
6		33			37	20				29		2.0
7	68		.02		42	18				25		
8	74				34	32				22		
9	77	50			35	21			35			
10	78	51				18			32			2.0
11	79	56							27	23		1.0
12		58			55				32	10		
13		38	.53		58	40			31	25		7.0
14	69						0.7		22	-1		
15	65						0.75					
16	51	35	.005			25						
17	54	37							19	0		
18	54	38							29	-1		
19		28			46				21	14		5.0
20					48	30			27	15		3.0
21					58	45	.3		30	2		
22	68									-3		
23	73	28			50	31						
24	73	34			53		1.45					
25	68	54				29			44		0.65	
26	62	46			43				36			
27		33	0.5		48	39	.015		36	32		0.5
28			0.41		42	33	.65					
29	48		0.04		32	28						1.5
30	53	43			49	35						
31	50	40	0.47						24	2		
Total			2.045				4.1				1.26	22.5

TABLE B-4. METEOROLOGICAL DATA

1974

Day	Month: January				February				March			
	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow
1					20	13		3		29	.08	
2	16	-5		0.5				1.0		29		
3	23	8		0.5				2	71		1.0	
4	26	10			19	8			37		1.0	
5	27				14	-13		2	52	31		
6				2.0	19	5		8	58	37		
7	18	3		1.0	20	-7			56	31		
8	13	-13		5	25	-17			59	31	0.7	
9	26	4			29	-8						
10	23	5		4				1				
11	29	13			24			Tr	38	22		
12	29				43	12			37	27		
13		-11			35	18			35	17		
14	34				18	5			41	12		
15	37	29			20	-8				33		1
16	43	27				6				25		2
17	26	23			34				43			
18	30	20		Tr	40				40		0.18	
19		28			35	34	0.09		35	23		
20	45		0.3		35	12			37	12		
21					43	23	0.3		34	25		1.5
22	34		0.2	0.5	33	31		4	39	17		2
23	37	32		Tr					31			2
24	40	23								0		
25		26			29	-5				-6		
26	50		0.4		35	1			37	20		3
27					46	17		Tr	34	23		
28	32	25			51	36			28	25	.2	3
29	40	26							33	24		
30					50	23						
31					39	15		0.1				
Total			.9	13.5			.39	21.1			3.16	14.5

(continued)

TABLE B-4 (continued
1974

Day	April				May				June			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1	45	31			61	36			75	42		
2	65	34			68	38						
3	63	35	0.62		55	41	.18		74			
4	50	34	Tr		60				82	60		
5	42	30	Tr				.20		82	54		
6	50				47	33			79	64	.31	
7			.38		55	22			78	68	.4	
8	34	19			41	37	.32		84		1.3	
9	46	18			51	35					.45	
10	58	21			62	30			66	63	.03	
11		40	.02				.25		63	44	.07	
12	68		.45				.05		69	42		
13					46	39	.33		73	47		
14			.23		72	46	.65		76	47	.04	
15	51	28			56	45						
16	59	24			59	45	1.75					
17	63	31				48			56	47	.13	
18	46	39	.64			43	.02		71	50		
19	51	23			68					52	.04	
20		20			72				84	50	.03	
21	71		.03		84	50			81	63		
22	60		.025		71	62						
23	42	36			68	53	.08					
24	59	26			59	41			70	44		
25	56	26							73	41	.03	
26	72	29							79	47		
27	77				65	34	.12		80	48		
28					64		.25		79	50		
29	69		.27		74	60	0.025		81	44		
30	64	57			71	52			80	50	.44	
31					72	56	.015					
Total			2.665				4.24				3.27	

(continued)

TABLE B-4 (continued)
1974

Day	Month											
	July				August				September			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1	85	52			77	51						
2	89	56	.3		78	59	.65				.75	
3		73				62	.62		64	37		
4			.17		78		.29		67	36		
5					78	51			69	36		
6		48			81	52				38		
7	90				80	51				42		
8	91				79	61	.19		79			
9	92	64			83	58			80			
10	80	67	.12						78	52		
11	77	52					.30		83	64		
12	84	44			80	56			80	63	.05	
13	43				81	67	.24		71	56	.02	
14					77	50						
15	82	51			82	52						
16	81	49				59	.90		68	35		
17	85	52							75	42	.02	
18	87	53	.13		82				67	35		
19	91	61	.42		86	52			82	40		
20					85	58			62	48		
21					86	58			64			
22	66	44	.12		84	63	.04					
23	77	58			80	64				23		
24	84	55									.05	
25	77	60	.02		79	45			64		.07	
26		61			89				76	34		
27					73	63	.6		73	50	.4	
28					71	45					.12	
29	78				75	48					.5	
30	75	53			76	48			48	39	.05	
31	78	53					.3					
Total			1.28				4.13				2.03	

(continued)

TABLE B-4 (continued)
1974

	Month											
	October				November				December			
	T	T	Precipitation		T	T	Precipitation		T	T	Precipitation	
Day	Max	Min	Rain	Snow	Max	Min	Rain	Snow	Max	Min	Rain	Snow
1	48	35	.1			61			37			.5
2	43	25	.03		69				45			
3	52	22					.2		32	24	0.3	
4		33	.04		43	35	.1		34	12		4
5	70				41	32	.8		34	15		
6			2.75		44	31				15		
7	52	35			54	24						
8	58	30				29			37			
9	56	33			59				29	16		
10	71	31				27	.18		34	16		.05
11	70	35					.34		34	16		
12		29			43		.05		35	26		
13			0.4		33	29		1.5	37			
14	56		0.76			25		2				
15	54	35						1.5		30		5
16	60	29				21	.1		35			1
17	56	35							32	29		.5
18		23			54				27	20		Trace
19			.04		52				31	21		6
20	41				45	43	.09		32	10		
21	51	16			40	32				21		1
22	64	37			40	25	.08					
23	58	42			59		.42		43			
24	63	28					.05		42			1
25		37	.045		32	19						
26	67				30	9			30	22		
27		27			30	24		2	37	23		
28	71				34							
29	62	42	.5			15			37			
30	71	52	.04			21			39	24		
31	73	57							34	20		2
Total			4.705				2.41	7.0			0.3	21.05

TABLE B-5. METEOROLOGICAL DATA
1975

Day	Month											
	January				February				March			
	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow
1												
2	30	7			34	11						
3	36	25		3	31				28	19		Trace
4				1	36	21				13		
5					33	25			34			3
6	32	13			31	23		2	37	31		
7	38	31				- 2			35	29		6
8	41	31	.65									
9	45	33								- 2		
10	53	33	1.58		21	8			30			Trace
11				1.5	31	1			35	6		
12					32	6			36	25		
13		11			24	3			33	13		
14	23	4		1	30	1				9		
15	26	8		1.5		21		4				
16	23	20		1.5					45			
17		2			33			.57	52			
18				1.5	32	30		.5	55	28		
19	34				32	22			51	35		
20	24	-6			38	25			52	29		
21	34	16		Trace	45	18			38	26		3
22	26	12		Trace			.12				0.35	
23	33	12					.08		45	23	0.2	
24		21	0.5		40	32	.05		50		0.2	
25	39		0.2		33	27		1.5	32	26		
26				1	32	30		1.5	30	13		
27		13			25	18		Trace	40	20		
28	41	21			34	22		1			0.3	
29	38		0.64									
30	31	17								9		1
31	31	23							47			
Total			3.57	12.0			.25	11.07			1.05	13

(continued)

TABLE B-5 (continued)
1975

Day	Month											
	April				May				June			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1	42	28										
2	31	25	0.15									
3	36	14					0.06					
4	36	12										
5		10							75			
6										50		
7	45											
8	40	16							67	40		
9	37	26							73			
10	47	29							72	50		
11		22							69	56	.36	
12									72	57	.02	
13	50	16								57		
14	50						.06		78			
15	55	34									2.05	
16	58	27							74	51		
17	66	20							79	63	.24	
18	67	48	0.63						83	64	.085	
19			0.05						86	66		
20							.28			66	.41	
21	56						2.55					
22	59	38							90	62		
23	61	45	0.35						83			
24	49	44							78	67	1.19	
25		42					.01		77	66		
26	60	21							81	57		
27										60		
28	44		0.63									
29	72	32							88			
30	65	42	0.48				.325		86	52		
31												
Total			2.29				3.285				5.025	

(continued)

TABLE B-5 (continued)
1975

Day	Month											
	July				August				September			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1	86	56			95	63			82			
2		52					.92		75	58		
3			.055						66	52	1.35	
4	88				86	54			72	54		
5					74	63	.065			52	.52	
6		57	.15		73	53			70			
7	86				76	43						
8	86	61				46						
9	77	49				53			65	37		
10	70	59			86				79	43	.035	
11	75	41			86				72	60	.2	
12					85	57				39		
13		47	.24				.58			32		
14			.04		79	50			65			
15	81	55				63			64			
16	87								65	42		
17	86	60			84	51			69	44		
18		62			71				69	52		
19	82		.52		74	56			66	57	0.86	
20					78	53	1.15				0.44	
21	81	52			77	58	.94					
22	84	54				60	1.4		60	46		
23	85	60				57	2.16		65	36		
24			.11		85				63	42		
25		53			82				54	43	.02	
26	84				81	62				47		
27	86	43	.19			52						
28	86	54										
29	91	54					3.5		66		.16	
30	93	59							68	44	.05	
31	96	61					2.2					
Total			1.305				12.915				3.635	

(continued)

TABLE B-5 (continued)
1975

Day	October				November				December			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1	54	43				37	.38		30			2
2	53	30					.6		34	20		.5
3		33			60		.04			11		
4	71	41			65	52			34	21		
5	72				70	49			58			
6	69	36			74	46					.23	
7	69	32			61	55	.32					
8	65	38							30	12		1.5
9	68	48	.04				.08		32	26		
10		41			50		.03		33	18		.5
11						29			32	27		2
12							.08			25		
13	82					32			58		0.4	
14	82	56				26					1.1	
15		60	.04						38			
16		34				20			32	23		
17	53	36							19	14		.5
18		41							14	7		
19									20	6		8
20	62						.41					
21		45			38	32			30	-6		
22	70	38			41				33			
23	75	47								16		
24		53	.03		35	20						1
25			.66			23		3				
26		27			27	5						
27	64	32				1		6				2
28		45										
29		31					1.15					
30		25			58							4
31		32							33			
Total			.77				3.09	9			1.73	22.0

TABLE B-6. METEOROLOGICAL DATA
1976

Day	Month											
	January				February				March			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1								2	32	25		.9
2	38	25				-11			33	18		.8
3				3	26	- 2			36	20		
4					25	16			48	30	1.25	
5	15	2			22	8			38	25		
6	31	20			21	3			30			
7	20	10		1.5		- 9			34			
8	16	3			24				35			
9		6		2	36				42	21		
10		3		3	48	36			40	29		1
11	31			1	38	30			39	16		
12	33	23			49	16			54		0.48	
13	33	30		5		34						1
14	25	17		1		8				19		
15	34	-10		2.5	58		.15		37			
16	30	12		1	38		.28		35	23		.5
17		-20			42	31			32	8		
18	27				49	32	.66		50	18		
19	32			.5	98	32			70	50		
20	29	20			48	26					0.84	
21				2			.4	.6				
22	20	11		.5					39	13		
23		0		2.5	30	7			56	23		
24					55	19			69	45		
25	30			3	60	28			59	39		
26	34				57	32			74			
27	23	-3			63	26					.37	
28	33	-6								26		
29	25	7		.5					60		0.1	
30		16		2.5					69	48		
31	29								44	38		
Total				31.5			1.49	2.6			3.04	4.2

(continued)

TABLE B-6 (continued)
1976

Day	Month											
	April				May				June			
	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow	T Max	T Min	Precipitation Rain	Precipitation Snow
1	43	33	.08						73			
2		32					.5		72	39		
3	63				43	32			76	39		
4						26				43		
5	57	23			78		1.8			46		
6	61	32	.1		42	36	.63					
7	55	30				26			86			
8	49	26				26			86			
9	59	19			70				87	56		
10			.11		71		.13		85	56		
11					59	42				66		
12	51	16			62	28						
13	62	22			71	31			88			
14	76	40	.015		73	43			85	61	.04	
15	80	59	.58				.4		84	66	.1	
16	82						.54		66	57		
17	82					49			77	48		
18			.47		61	-			84	58	.51	
19	66	51			60	29				45		
20	62	48			76	45						
21	71	44	.315		70	42			77			
22	59	45							79	59		
23	60	33	.05						80	53	.34	
24			1.6		65	36	.015		70	56	.34	
25				3	65	40				62		
26	36	24			70	39				53		
27	48	28			-	40			86			
28	59	27			74	52			81		.19	
29	63	27					.76		76	55		
30	62	33							60	56	1.39	
31												
Total			3.32	3			4.775				2.91	

(continued)

TABLE B-6 (continued)
1976

Day	Month											
	July				August				September			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1		53					.065		83	50	.04	
2		47			73	42						
3					80	42						
4					78	43				37		
5	86				80	59	.39					
6	86				81	53						
7	83	56			80	40				86		
8	82	53							89	51		
9		52			85				67	54	.93	
10					83	46				43		
11	91				88	62				43		
12	77	54			83	66	.09		81			
13	82	42			83	66			80			
14	93	54					.5		81	48		
15	90	59							59	50		
16		60			76	38			63	51	.02	
17		51			81	42				53		
18	85				85	43			78			
19	83				87	52				42	.16	
20	80	64	.66			53			67			
21		60			91				60	34	.18	
22	84	54							59	28	.11	
23			.025		84	51			59	39		
24		56			86	49				24		
25					83	54			68	31		
26	87		.03		82	59					.44	
27	88	62			93	57	.02		62			
28	73	55	.2				.16		59	26		
29	76	61							67	36		
30		54			69	34			74	37		
31	84				83	44						
Total			.915				1.225				1.88	

(continued)

TABLE B-6 (continued)
1976

Day	Month											
	October				November				December			
	T Max	T Min	Precipitation		T Max	T Min	Precipitation		T Max	T Min	Precipitation	
			Rain	Snow			Rain	Snow			Rain	Snow
1		34			51	16			26	-7		3
2	81				52	34			11	-1		
3					45	22				-16		2
4	78	37			40	24				3		
5	72	49	.3		42	24			30			
6	50	38	.95		50				30			2
7		31							20	2		
8		26			33	10			20	-7		.5
9					47	24			25	-5		1
10					40	20	.04		41	25		
11	65				34	17						
12	73				37	8						
13	63	39				21				-6		
14	61	25			40				39	11		
15	57	43			45				34			
16					48				34	19		
17									36	22		
18	47	13			46					7		
19	40	25	.11		47	31			47			
20	47	29							27			.5
21	43	27	.13						22	1		
22		25				14				4		
23		19			31					-7		2
24	47					20						
25	47		.07		54				33			
26		24			53		.32					4
27	41	10					.64					
28	47											2
29					16	-1		1				
30					19	5		4		-24		
31	52											3
Total			2.02				1.00					20.0

TABLE B-7. METEOROLOGICAL DATA
1977

	Month											
	January				February				March			
	T	T	Precipitation		T	T	Precipitation		T	T	Precipitation	
Day	Max	Min	Rain	Snow	Max	Min	Rain	Snow	Max	Min	Rain	Snow
1					29	8			29	5		
2					28	13		1	39	11		
3	24			2	29	19		2	36	27	0.2	
4	26	6				19		1	42		1.2	
5	26	-7										
6	24	-4		1		-15						
7	19	4			25				43	26		
8				3	27	6				27		
9		-20			37	12			61			
10	15			4	47	34			63	29		
11	16	7		1	45	18			69	35		
12	13	-10		2	42	27		.5			.29	
13	21	- 9		2	32							
14	23				27	22		Trace	49	40		
15	19			1	18	5			72	39		
16					18	-11			46	31		
17	11	-24		1	29	-8			40	18		
18		1			38	25				28		8
19	24								41			
20	22	5										Trace
21		6				-2			41	18		.5
22		1			46				43	27		
23	27				46	30	.12		35	23		
24	29			1	46	32	.46		36	15		
25	27	22		Trace	33	27		Trace		19		
26	27	11		4	34		0.2		67			
27		-2					2				0.12	
28		-5		4	32	22				45	0.57	
29				1					69		0.2	
30	14			2						42		
31	20			4							0.04	
Total				33			2.78				2.62	8.5

(continued)

TABLE B-7 (continued)
1977

Day	Month											
	April				May							
	T	T	Precipitation		T	T	Precipitation		T	T	Precipitation	
	Max	Min	Rain	Snow	Max	Min	Rain	Snow	Max	Min	Rain	Snow
1		22	.02									
2	66		.63		72							
3					68	37						
4	46	31	.22		65	47						
5	36	31	.045		76	51						
6	36	21				47						
7	53	21			77							
8		19										
9		20			58	28						
10	79				67	28						
11	80				72	30						
12	81	47			77	40						
13	75	54	Trace			51						
14	64	39				48						
15		37			84							
16	77				86							
17		45	.075		84	60	.05					
18	85				86	58						
19	75	51			90	54						
20	77	57	1.09		90	56						
21	73	59	.28									
22	63	51	.04				.14					
23					87	58						
24			.23		88	60						
25	55	34	.89		89	56	.22					
26	62	28			80	49						
27	73	35			89	45						
28	52	37										
29	63	25										
30	73	30										
31					77	50	.56					
Total			3.52				.97					